



Brief QC Checks for Aerial Photogrammetry Products

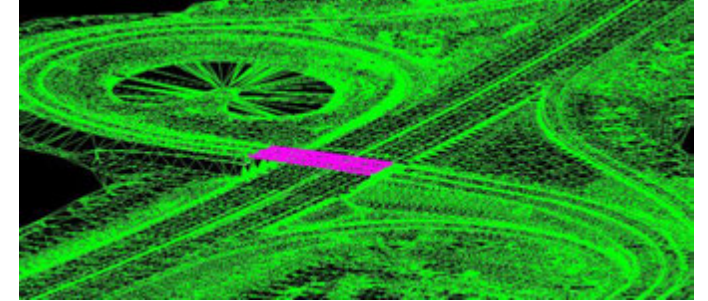
Brief QC Checks for Aerial Photogrammetry Products

Agenda

1. Photogrammetry

Overview of Photogrammetry

Photogrammetric Softcopy Systems



2. Digital Direct Referencing of Sensors (Camera Systems)

Camera Features (Metric and Non-Metric)

Sensors (Camera Systems)

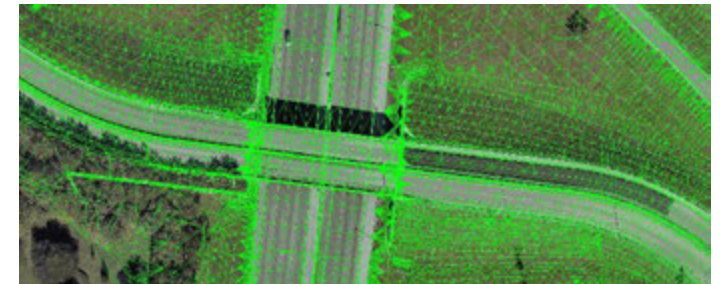


3. Check results in Microstation / Geopak

Edit and prepare AT results (ISAT, BINGO, Socet Set, etc.)

Review delivered 3D map (LAMP Data)

DTM compare in Geopak

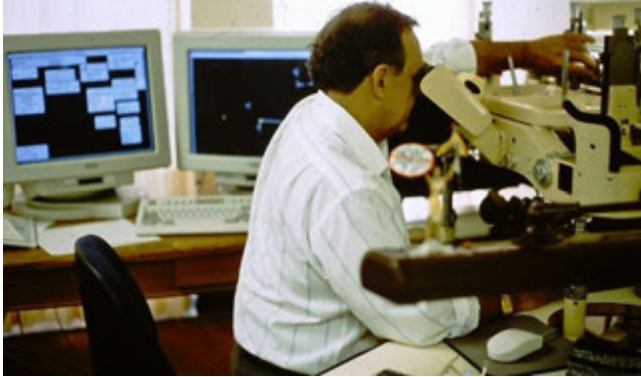


Analogue Aero-Triangulation

<https://www.youtube.com/watch?v=UmVsmbI7cmM>



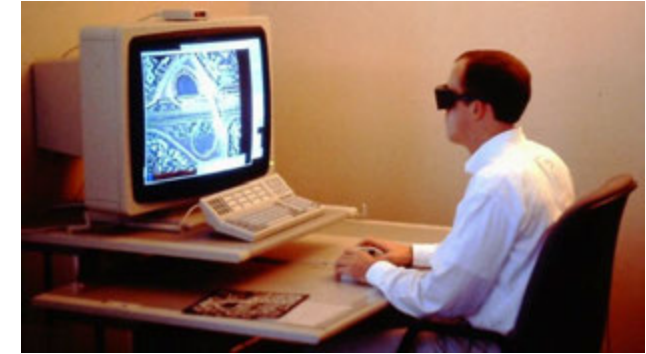
Analytical Digital Aero-Triangulation



Semi-Analytical Photogrammetry 1970s



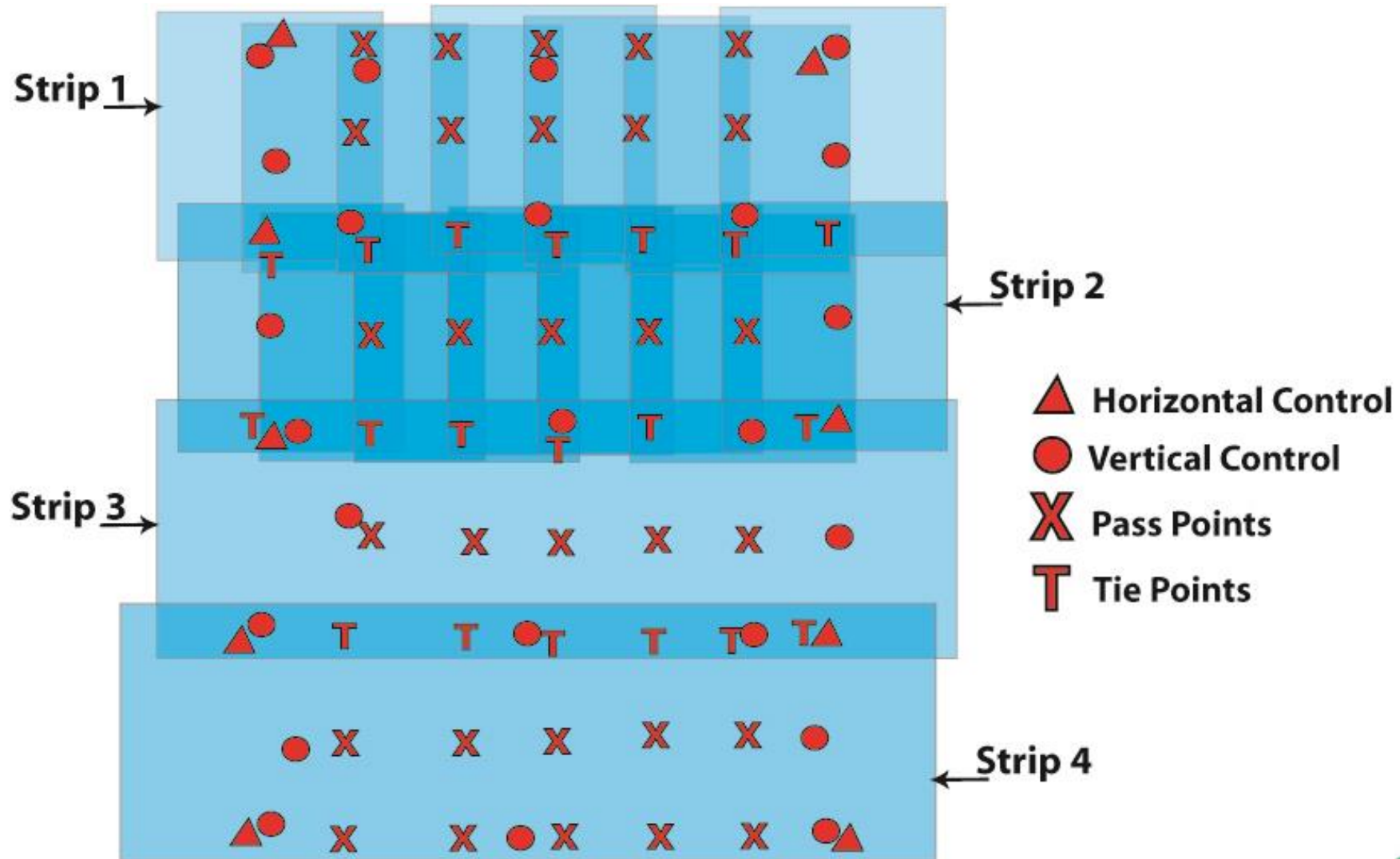
Analytical Photogrammetry 1980s



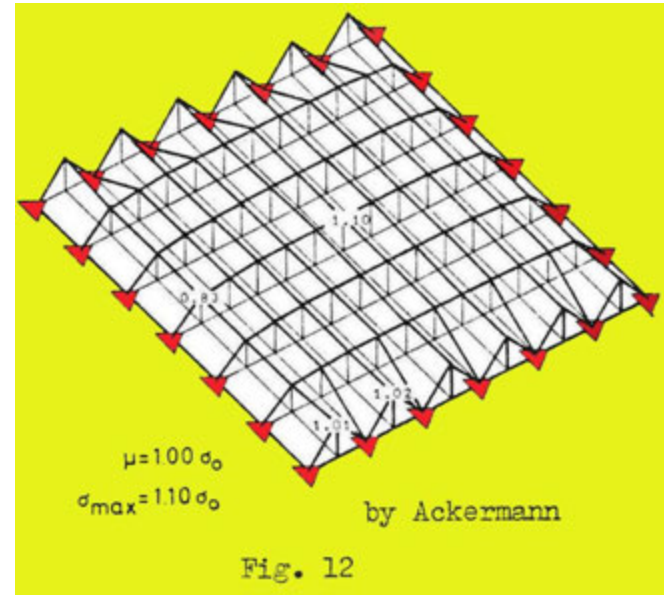
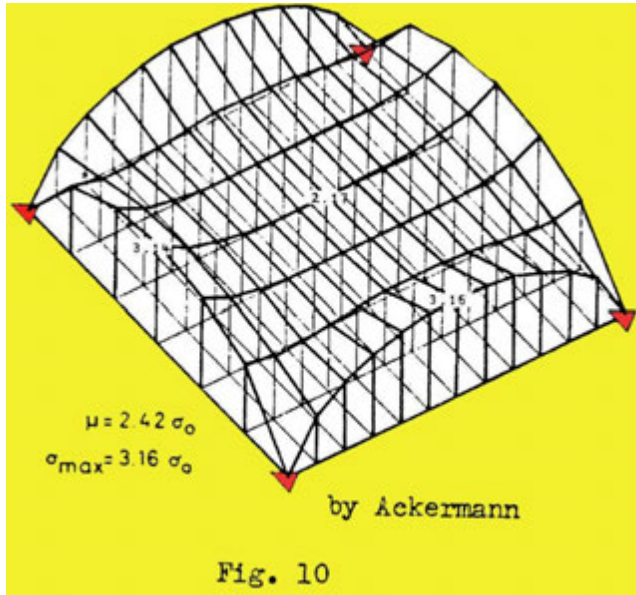
Softcopy Photogrammetry 1990

Inpho	ISAT	SocetSet	BINGO	VR-AeroSys	BLUH	Softplotter	ERDAS
PAT-B	Densified	GPF	Itera	*ptb, VRAT	BLUH.lst	ptb	ptb

A typical Aerial-Triangulation Layout



Professor Dr. -Ing. Dr. Fritz Ackermann 80 years – Professor, Innovator and Developer of Modern Photogrammetry



The programme system for block triangulation was to be as universal as possible, capable of future expansion, even if it was not possible to develop all its variations immediately. In particular it was to fulfill the following requirements:

- although intended for large computers (CDC 6600), the programme should not be restricted to them.
- as far as the computer programme is concerned, the block size should in principle be unlimited. Total capacity of the computer determines the limits.
- This important requirement means two things: on the one hand it should be possible to adjust even extremely large blocks in large computers, if necessary with computing times of several hours. On the other hand, computers with small central processing units

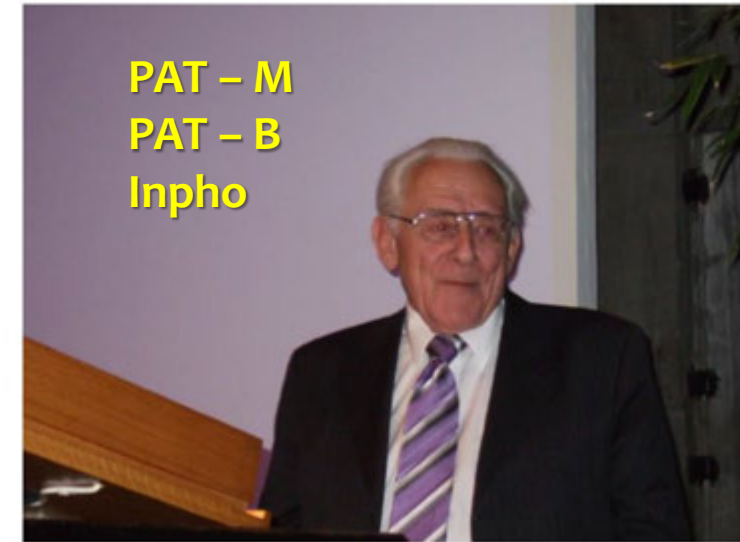


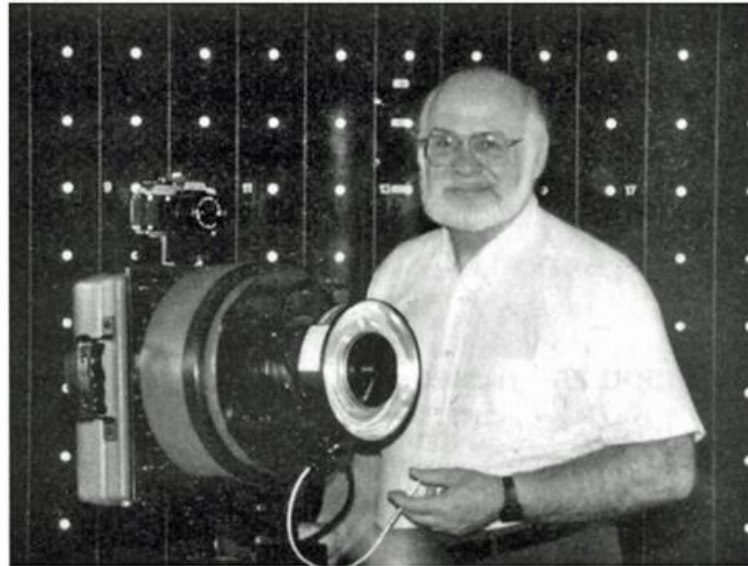
Abb. 7: Professor FRIEDRICH ACKERMANN nach seiner Dankesrede am 6.11.2009.



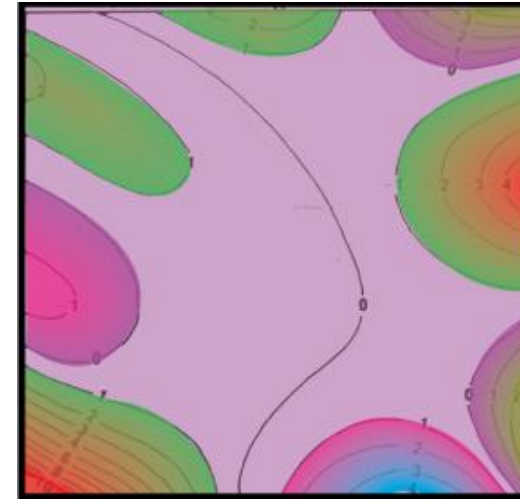
The first CDC 6600 was delivered in 1965 to the [CERN](#) laboratory near [Geneva, Switzerland](#)

Self-Calibration

Dr. Brown introduced Self- Calibration in the bundle adjustment.



Dr. Duane Brown
History of Photogrammetry
Center for Photogrammetric Training



Anomalous Distortion

ASPRS

Self calibration Improves:

- **the accuracy**
- **the reliability of the photogrammetric adjustment**

<http://www.geodetic.com/v-stars/what-is-photogrammetry.aspx>

Helava Associates - SOCET SET

A Glance at the History



Dr. Uuno "Uki" Vilho Helava

- Brilliant Finnish Scientist
- One of the fathers of photogrammetry
- One of the founders of Helava Associates, which provided digital photogrammetric workstations for the Defense Mapping Agency in the early 1980s

SOCET SET's provenance is special too. Its roots began in the early 1980s. Helava Associates, a small company set up in the suburbs of Detroit by Uki Helava and some close colleagues, worked as a sub-contractor to General Dynamics on a succession of contracts to provide digital photogrammetric workstations for the Defense Mapping Agency (DMA). General Dynamics acquired Helava Associates in 1986. SOCET SET was launched as a commercial product in 1990 on Sun hardware. At that time too, Helava Associates moved to sunnier climes in San Diego, California. In 1991, a distribution relationship was formed between General Dynamics, Helava Associates and the Swiss company Leica, whose ancestor companies Kern and Wild had made the running in analog and analytical photogrammetry just as Helava had in digital. General Dynamics divested its Electronics Division, including Helava, as GDE Systems, now part of BAE SYSTEMS. Meanwhile, in 1997, Leica Geosystems (one of several companies formed as Leica split up its huge, privately owned organization) and GDE set up LH Systems, a joint venture company designed to develop, market, sell and support systems for airborne imaging and photogrammetry. By then SOCET SET had evolved into a clear world leader (the Windows NT® version was added in 1998). Gradually, as computers developed, the product moved away from dependence on specialized, custom-built hardware towards off-the-shelf processors and peripherals. Meanwhile functionality had broadened considerably in terms of sensors, formats, algorithms and output products. The ORIMA and PRO600 components came from the Leica side, where they were supplied on its SD2000/3000 analytical plotters.



Autometric Softplotter- ERDAS OrthoMAX

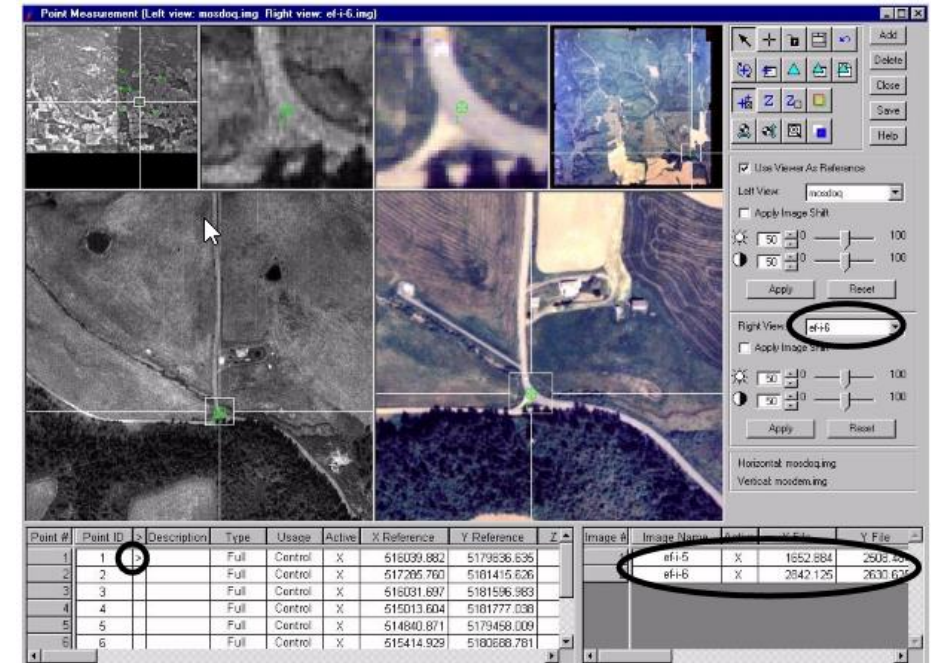


Dr. Fred Doyle

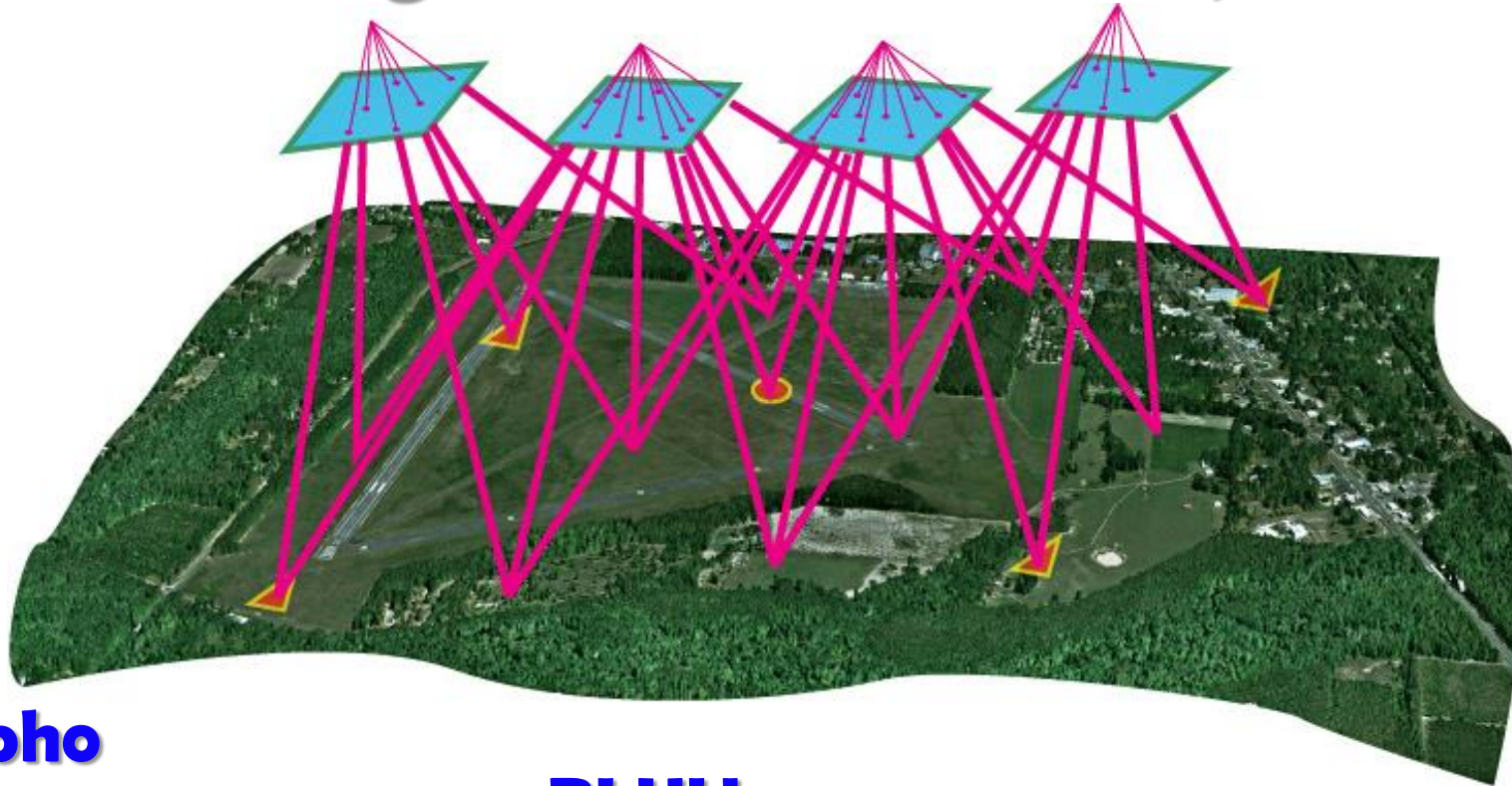


Figure 12. Bunker-Ramo UNAMACE stereo plotter for post-processing of rectified Corona transparencies AMS 1:250,000 Pictomap.

The aero-triangulation software used was various editions of MUSAT (Multiple Station Analytical Triangulation) developed by the Autometric Operation (first headed by Fred Doyle, later by Atef Elassal as the Team Leader for the various MUSAT versions) for the Army Map Service, then Army Topographic Command (TOPOCOM), then DMA/HTC, and then NIMA.”



Aerial Triangulation - Bundle Adjustment



- **Trimble Inpho**
- **Aerosys**
- **Leica LPS**
- **SocetSet GXP**
- **Vexcel UltraMap**

- **BLUH**
- **BINGO**
- **Intergraph ISAT**
- **RACURS Photomod**

- **Albany**
- **JFK**
- **PC Giant**
- **KLT Atlas**
- **ERDAS**

Trimble Inpho

The image displays the Trimble Inpho software interface, which is used for digital photogrammetry and laser scanning data production. The main window shows a menu bar (Project, Stand-Alones, Tools, Window, Options, Help) and a toolbar with icons for various sensors and processing tools. The 'New Project' section offers options like Aerial Sensor, Satellite, Pushbroom, A3-SLF, Lidar Preprocessing, Terrain Editing, and Aerial Multi-Head System. The 'Stand-Alones' section includes Orthovista, SeamEditor, DTMaster, and LPMaster. The 'Tools' section features Image Commander, DTMTToolkit, Transformation, and DPM... The 'Options' section includes Preferences, Language, and E-Mail Settings... The 'Help' section includes Support, Learn, WebAdmin, and Request Trimble.

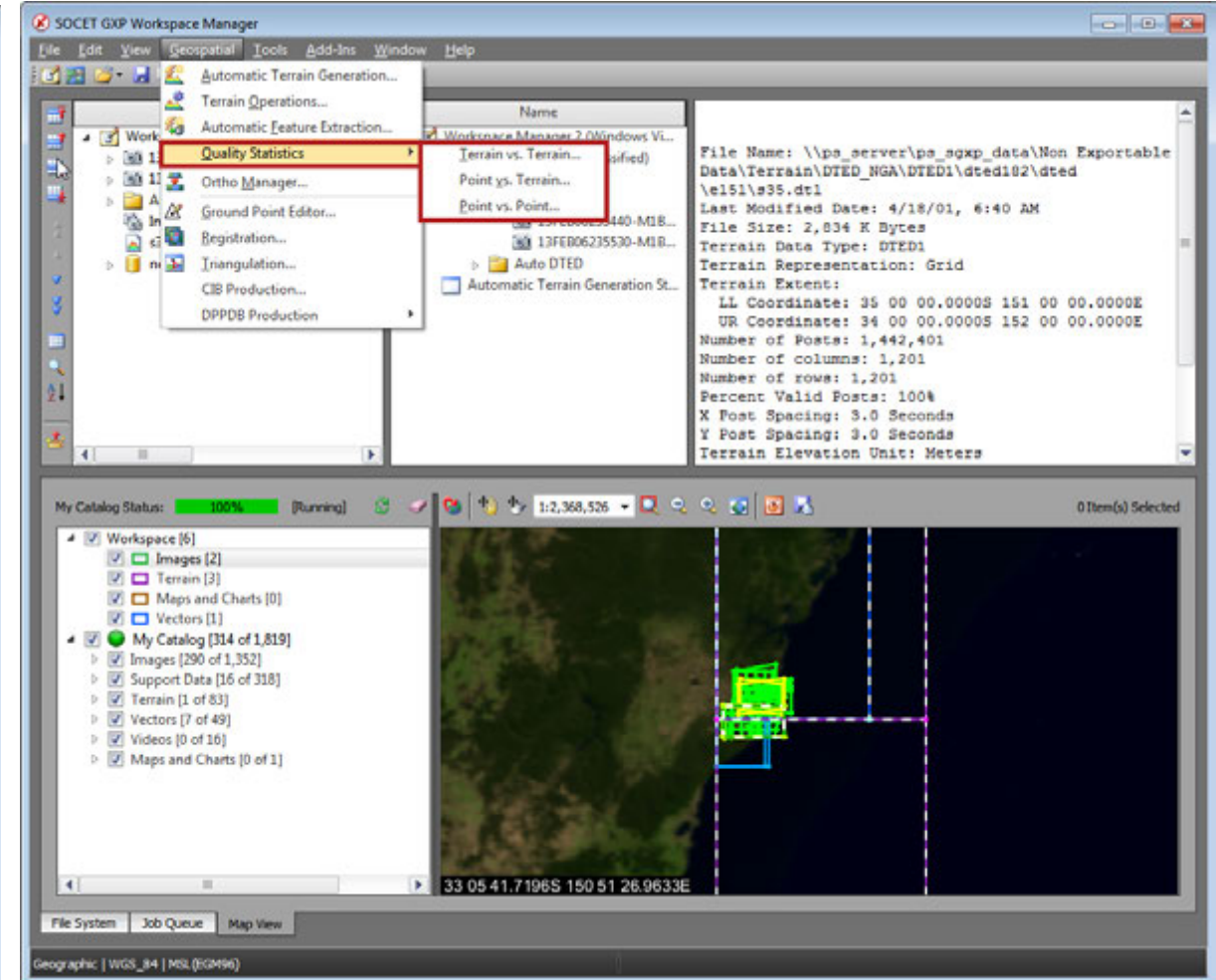
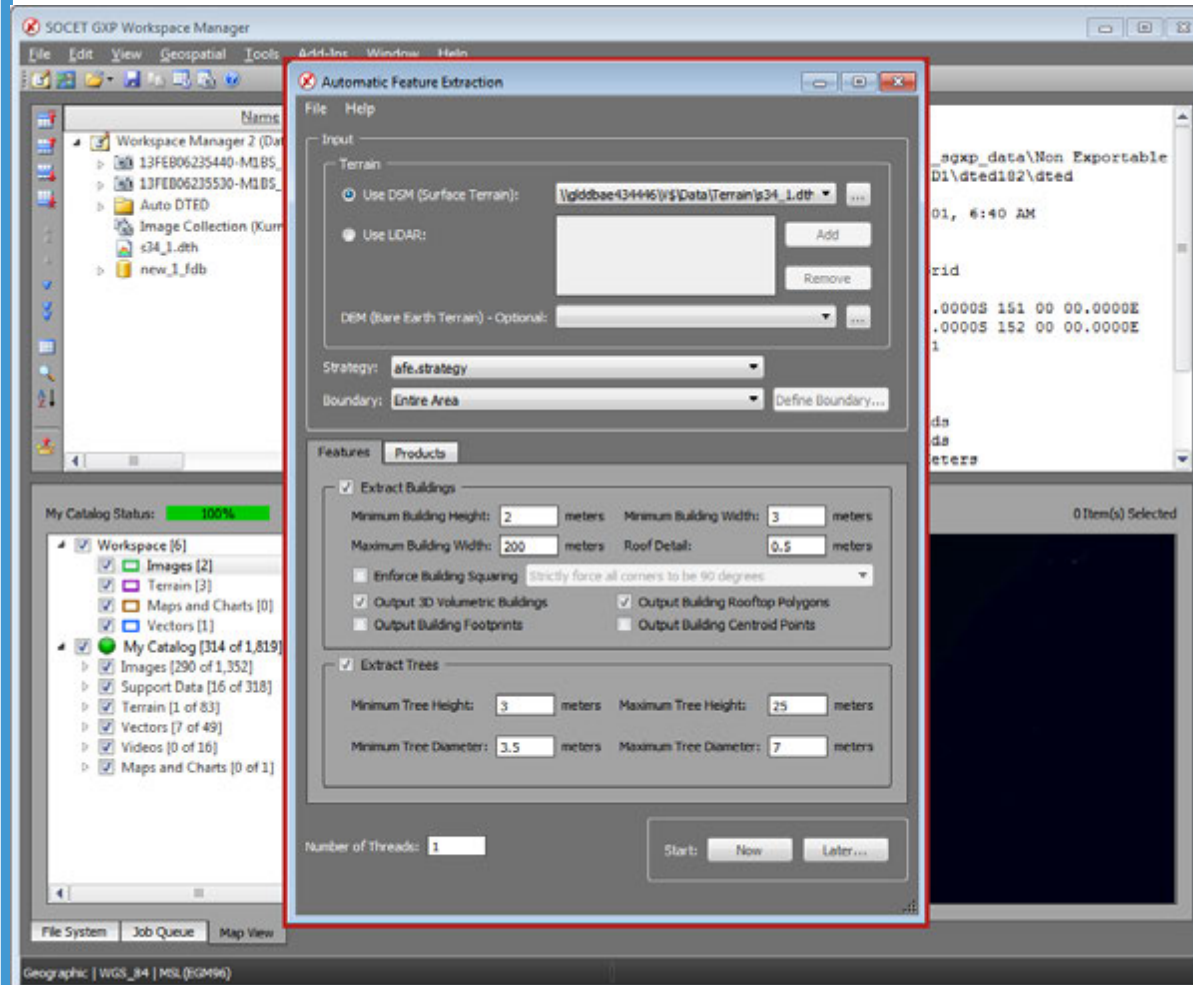
The 'Add New Camera' dialog is open, showing the following settings:

- Camera ID: Demo
- Sensor type: CCD Frame
- Brand: DCS 660
- Model: Phase1_IQ160-51mm, Phase1_IQ180-51mm, Pictometry 2x4K, Pictometry 3x2K, RCD30_60_150mm, RCD30_60_50mm, RCD30_60_80mm, RCD30_80_150mm, RCD30_80_50mm, RCD30_80_80mm

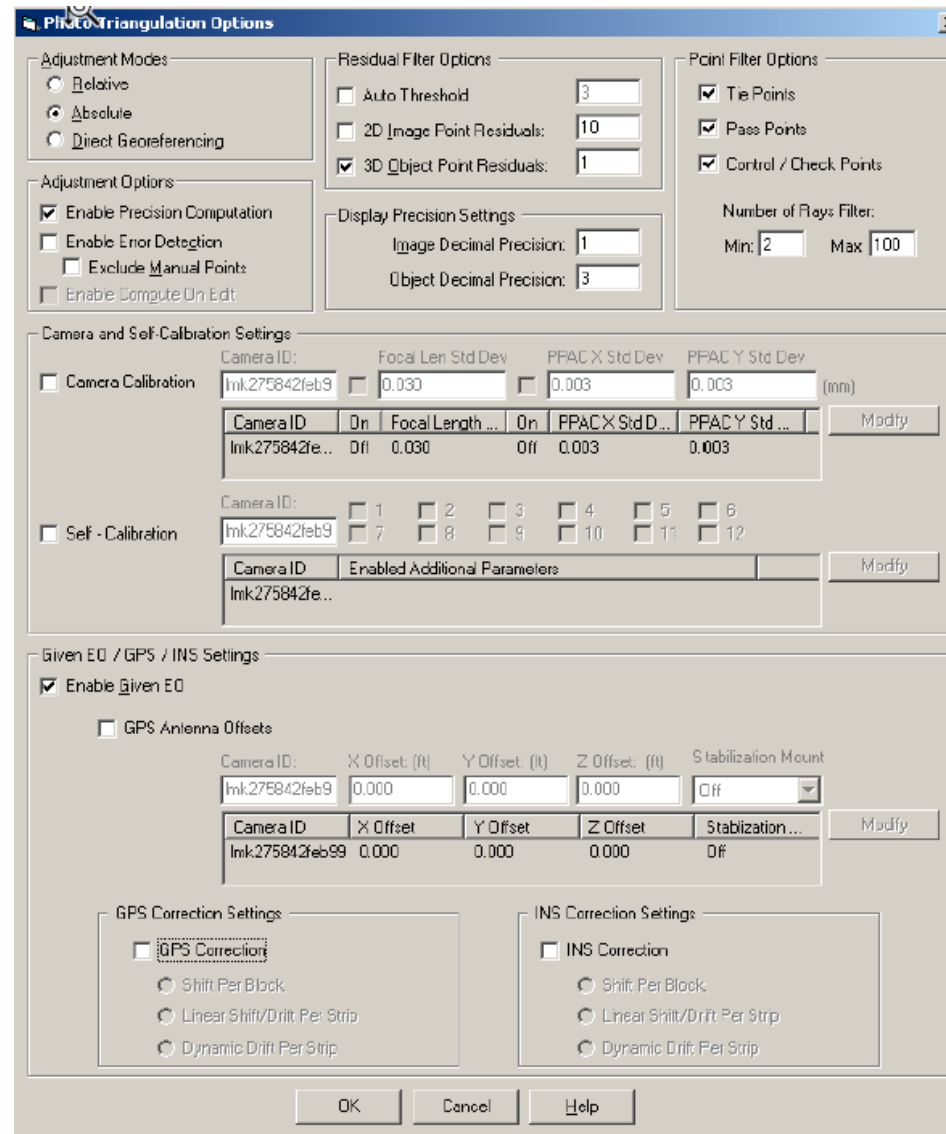
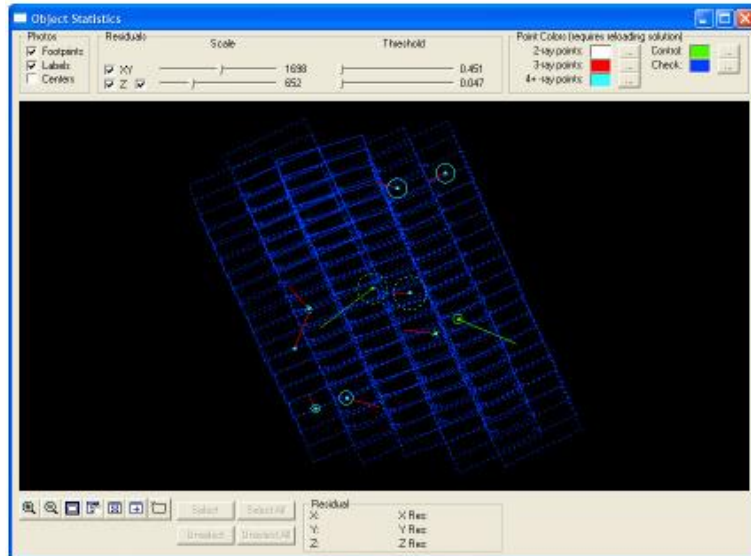
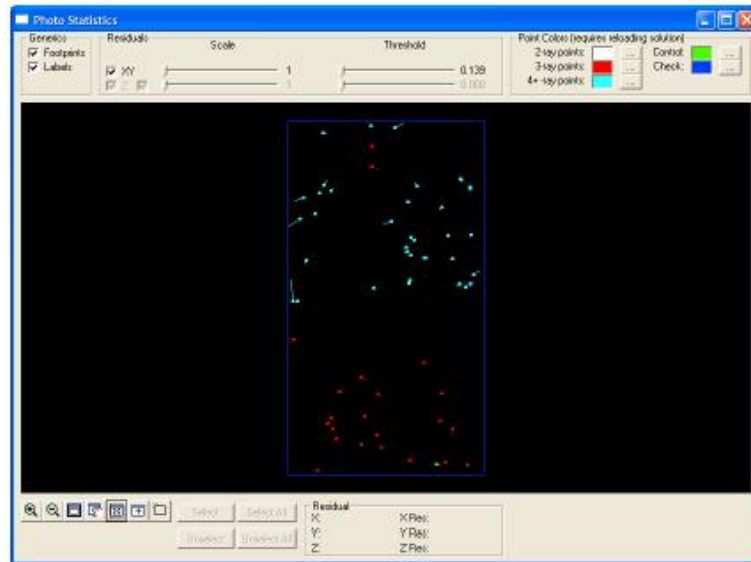
The 'Import Exterior Orientations' dialog is also open, showing the 'Select data source' section. The 'Format type' is set to 'ASC - ASCII Text'. The 'Data Extraction' section is set to 'Both, point and line'. The 'Import Data Preview' table is shown below:

ID	East X	North Y	Height Z	Pfu / Pitch	Omega / Roll	Kappa / Yaw	S
P1-10000-10000-10000_01_001.tif	2164521.80	156442.53	521.02	-0.57	0.06	-7.25	RCD30_50mm
P1-10000-10000-10000_01_002.tif	2164518.84	156438.13	521.96	-0.85	-0.02	-7.22	RCD30_50mm
P1-10000-10000-10000_01_003.tif	2164519.33	156432.47	522.77	-0.85	-0.07	-7.25	RCD30_50mm
P1-10000-10000-10000_01_004.tif	2164521.80	156425.13	524.25	-0.86	0.02	-7.26	RCD30_50mm
P1-10000-10000-10000_01_005.tif	2164523.10	156418.28	522.25	-0.52	-0.01	-7.26	RCD30_50mm
P1-10000-10000-10000_01_006.tif	2164433.26	156410.87	528.95	-1.30	-0.06	-7.34	RCD30_50mm
P1-10000-10000-10000_01_007.tif	2164514.85	156402.20	526.24	-0.57	-0.11	-7.32	RCD30_50mm
P1-10000-10000-10000_01_008.tif	2164512.75	156394.46	523.06	-0.99	-0.07	-7.25	RCD30_50mm
P1-10000-10000-10000_01_009.tif	2164472.23	156389.29	521.71	-1.01	-0.09	-7.37	RCD30_50mm

BAE - SOCET SET GXP workflow



Hexagon Intergraph Zeiss ISAT

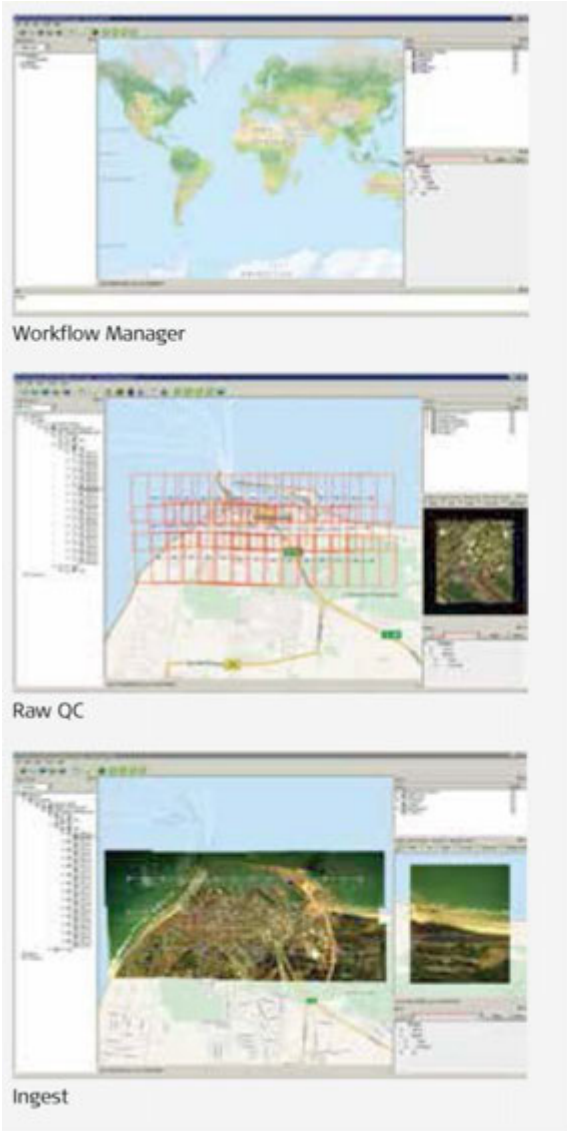


Cardinal System VrAirTrig



The VrAirTrig Layout window

Leica HxMap Workflow



Combined data acquisition & processing

To reach highest efficiency, post-processing has been tightly integrated with data acquisition. HxMap can be enabled for individual sensor types. For flexible production, scalable and application-specific software modules are bundled with the matching hardware.

RealWorld is designed for Leica RCD30 and Leica DMC III based large area mapping projects in 2D, whilst RealCity supports you with your smart city and 3D city modelling applications.

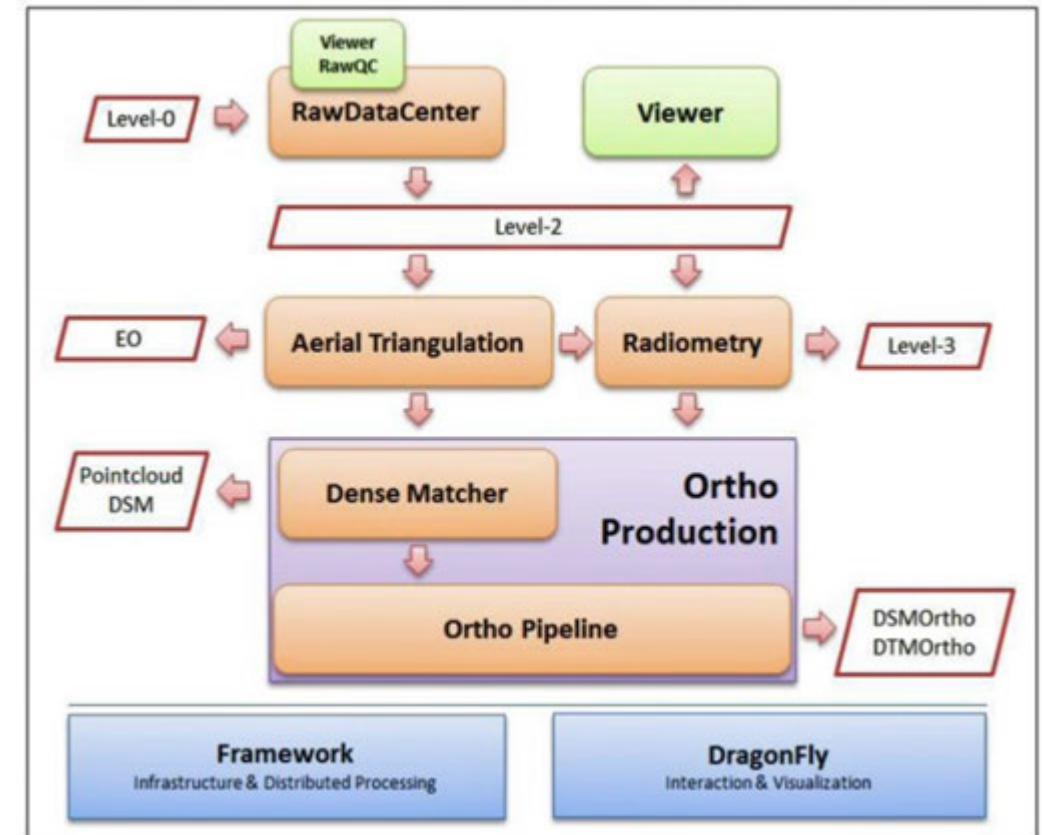
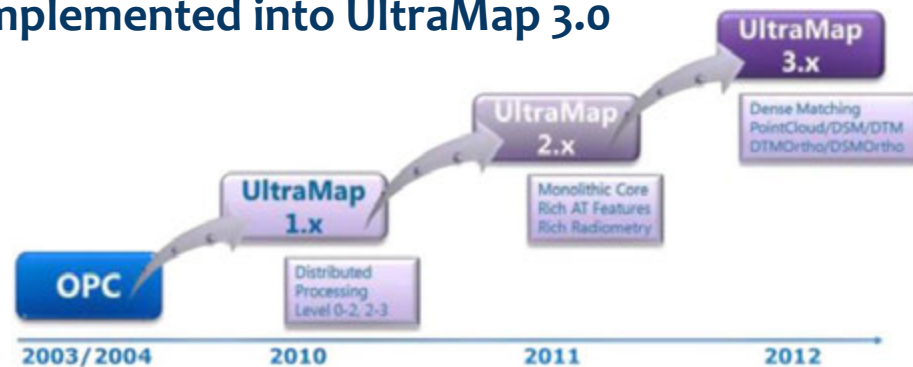
HxMap modules	RealWorld	RealCity
Enabler Enabler, Workflow Manager	●	●
Provider Ingest, Raw QC	●	●
Core APM, AT, Infocloud, Ortho Generator, Ortho Mosaic	●	●
3D Modeller Basic City Modeller, Texture Mapper, 3D Editor	○	●
3D Modeller Advanced Building Finder, 3D Mesh	○	○
SDK Developer's Kit	○	○

● = Standard ○ = Optional

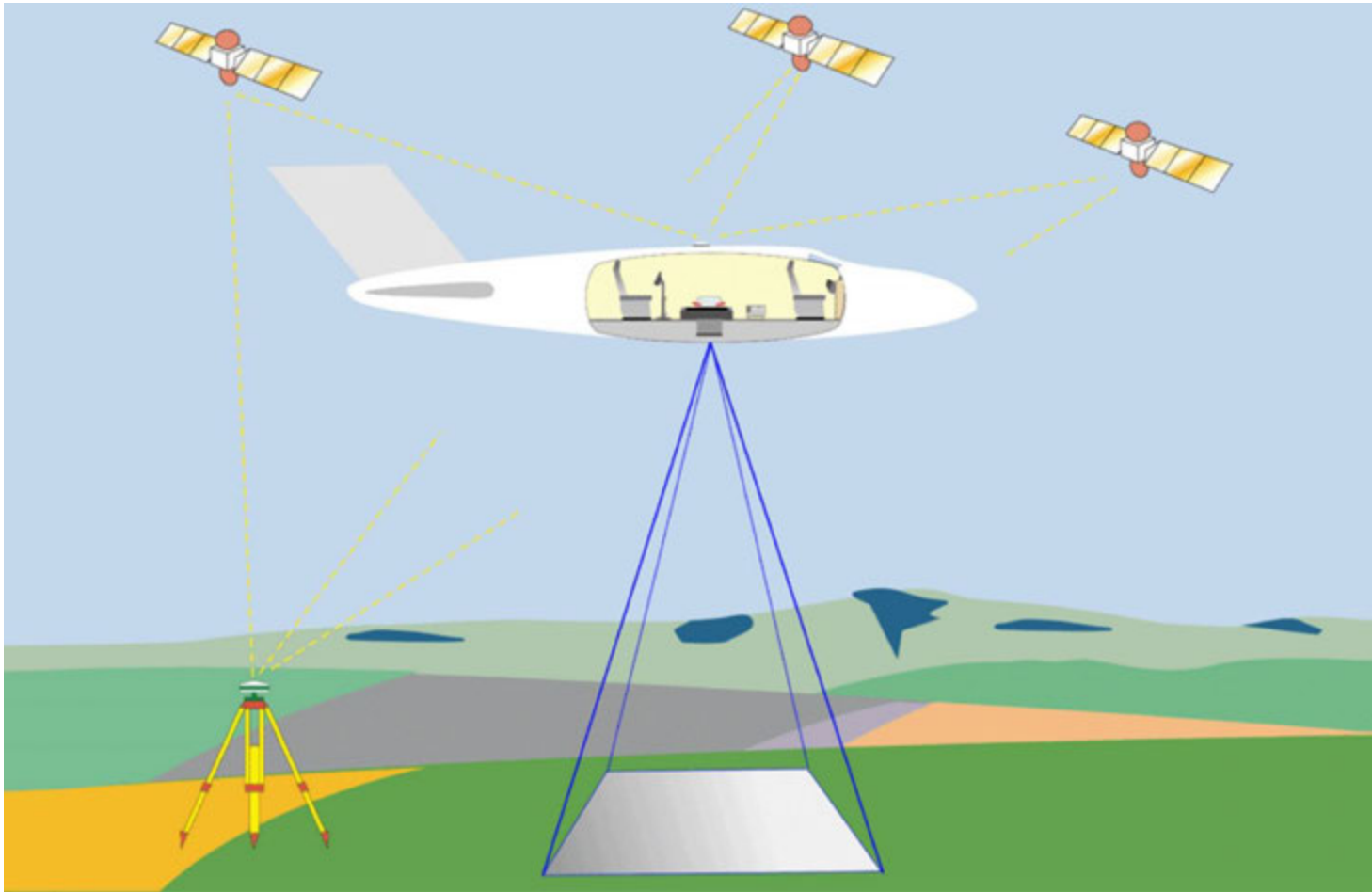
Vexcel Umap

Starting 2007 a dense matching algorithm and an automated ortho /true-ortho workflow has been developed by Vexcel Imaging GmbH that has exclusively been used for the automated 3D city model production of Microsoft's Virtual Earth project and is now also in use for the production of the current BING maps platform.

This famous automated workflow has now been disclosed and has been implemented into UltraMap 3.0



Leica RCD30 Digital Direct Reference System (DRS)



QC Checks for DRS:

1. **Lever Arms Offsets**
2. **Boresight Calibration - 3 months**
3. **Consistent GEOID model**
4. **Base Station Antenna Offsets**
5. **Desired Coordinate Output.
e.g. SPCS, LL**

GNSS/INS –WPK to RPH

Project: XXXXXX
 Program: Inertial Explorer Version 8.50.2923
 Profile: STATE PLANE(OPK)
 Source: Features/stations(Smoothed TC Combined)

Datum: NAD83(2011), (conversion NAD83(2011) to NAD83(2011) (Same))
 Master 1: Name TALH, Status ENABLED
 Antenna height 0.000 m, to ARP [LEIAR20(NONE)]
 Position 30 23 47.48352, -84 21 21.03548, -5.856 m (NAD83(2011), Ellipsoidal hgt)
 Position 30 23 47.48352, -84 21 21.03548, -5.856 m (NAD83(2011), Ellipsoidal hgt)
 Master 2: Name PRRY, Status ENABLED
 Antenna height 0.000 m, to ARP [LEIAR20(NONE)]
 Position 30 04 40.11913, -83 34 28.60936, -12.931 m (NAD83(2011), Ellipsoidal hgt)
 Position 30 04 40.11913, -83 34 28.60936, -12.931 m (NAD83(2011), Ellipsoidal hgt)
 Remote: Antenna height 0.000 m, to L1PC [Generic(NONE)]
 IMU to GNSS Antenna Lever Arms:
 x=-0.624, y=-5.173, z=2.319 m (x-right, y-fwd, z-up)
 Body to Sensor Rotations:
 xRot=0.000, yRot=0.000, zRot=0.000 degrees (Rotate IMU into Vehicle Frame)
 Geoid: GEOID03(CONTUS)CURRENT.wpg (Absolute correction)

Map projection Info:
 Defined grid: US State Plane, FL North (903)
 U.S. State Plane for FL North (903)

W-P-K Settings:
 System: Map (US State Plane, FL North (903))
 Order: W primary, P secondary, K-tertiary
 Axes: x-forward, y-left, z-up (conventional frame)
 Boresight: On (BX=-0.23000, BY=-0.18000, BZ=0.96000 deg)

Station	Easting (usft)	Northing (usft)	H-MSL (usft)	Omega (Deg)	Phi (Deg)	Kappa (Deg)
1000_01_001.tif	2160703.229	537156.521	456.462	-0.276735	-0.123096	348.167343
1000_01_002.tif	2160774.288	537141.954	454.549	-0.263680	-0.131872	348.175778

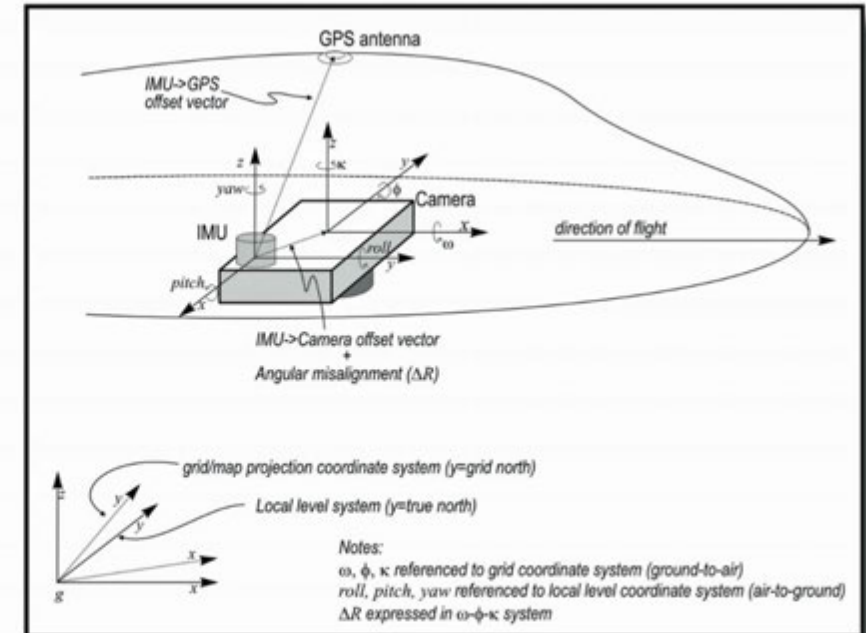


Figure 6: Relation of Omega-Phi-Kappa (WPK) to Roll-Pitch-Heading (RPH)

Trimble Applanix PosPAC - Boresight Calibration

20160930_Boresight_Results_Report.txt - Notepad

File Edit Format View Help

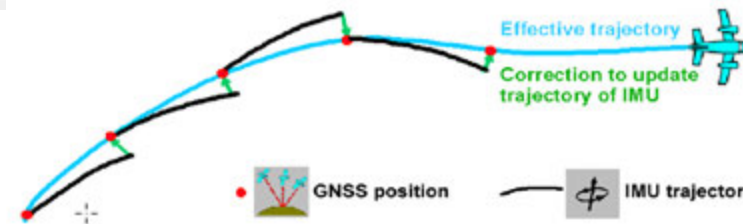
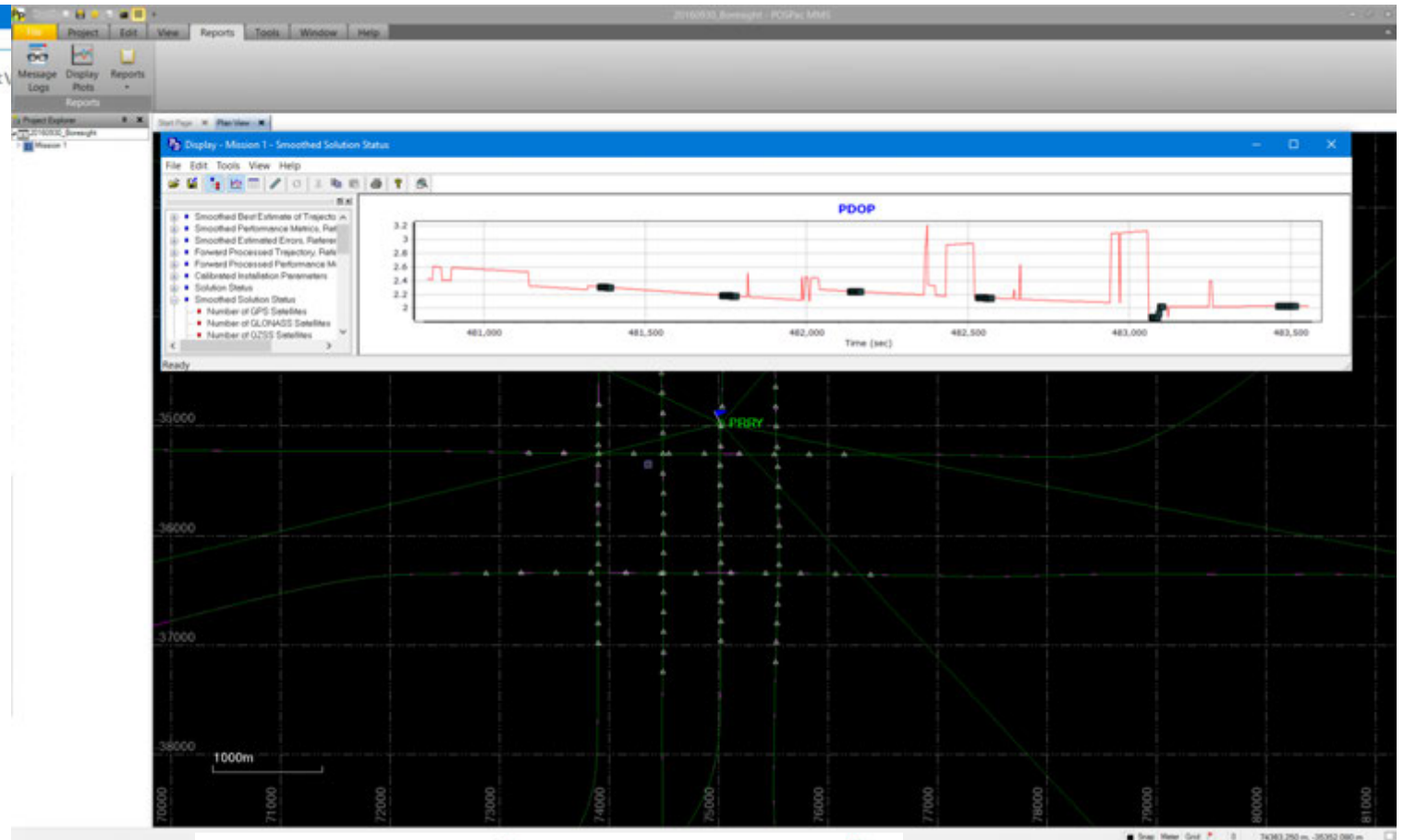
Project Name: Mission 1
 Processing Path: \\codata\shares\CO\SURMAP\LAB\PosPac MP5\Projects\20160930_Boresight\
 Camera Type: DMC
 Date: 11/21/2016
 Time: 1:01:39 PM

Project Configuration

Number of photos: 80
 Number of strips: 6
 Number of GCPs: 16
 Number of Check Points: 0
 Number of tie/pass pts: 1006
 Degrees of freedom: 6165
 Focal length(mm): 120.000
 Principal Point Offset in x(mm): 0.000
 Principal Point Offset in y(mm): 0.000
 Image measurement x_SD(micron): 12.000
 Image measurement y_SD(micron): 12.000
 Minimum Ground Parallax(USFoot): 0.016
 Maximum Ground Parallax(USFoot): 5.231
 Kappa Cardinal Rotation(Deg): 180.000
 Nominal Photo Centre SD(Meter): 0.050 0.050 0.050
 Nominal IMU Angle SD(Deg): 0.005 0.005 0.008
 Nominal GCP SD(USFoot): 0.200 0.200 0.200
 Boresight Angles(Arcmin): -1.242 -0.209 3.005

Calibration Result

Number of Iterations: 3
 RMS of GCP Residuals(USFoot): 0.101 0.120 0.163
 RMS of Check Points Residuals(USFoot): N/A



Antenna offset for - Inertial Explorer GNSS/IMU systems

QC Check for:

1. Lever Arms Offsets
2. Boresight Calibration - 3 months
3. Consistent GEOID model
4. Base Station Antenna Offsets
5. Desired Coordinate Output. e.g. SPCS, LL



FDOT FPRN Data supplied in RINEX files

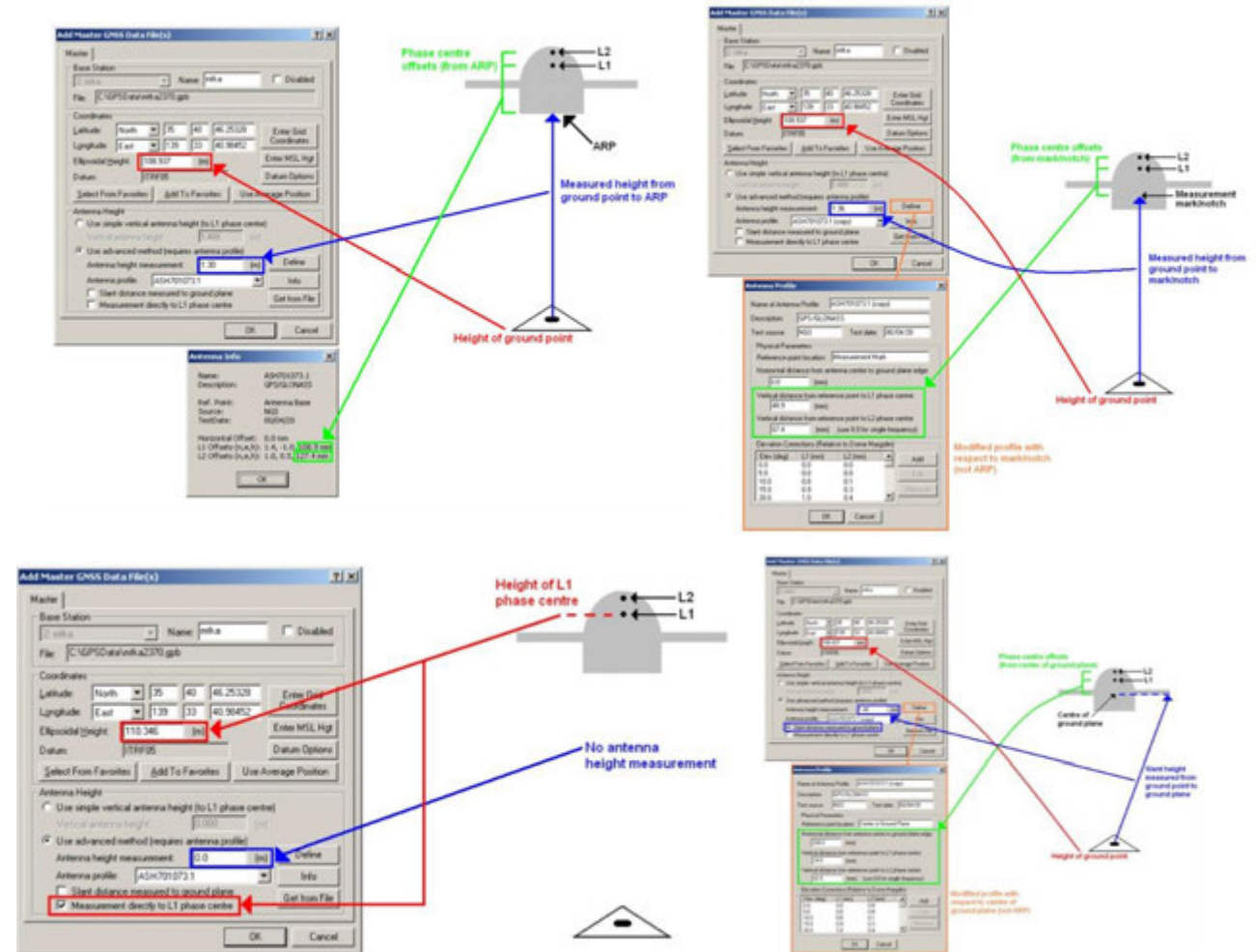


Services RINEX

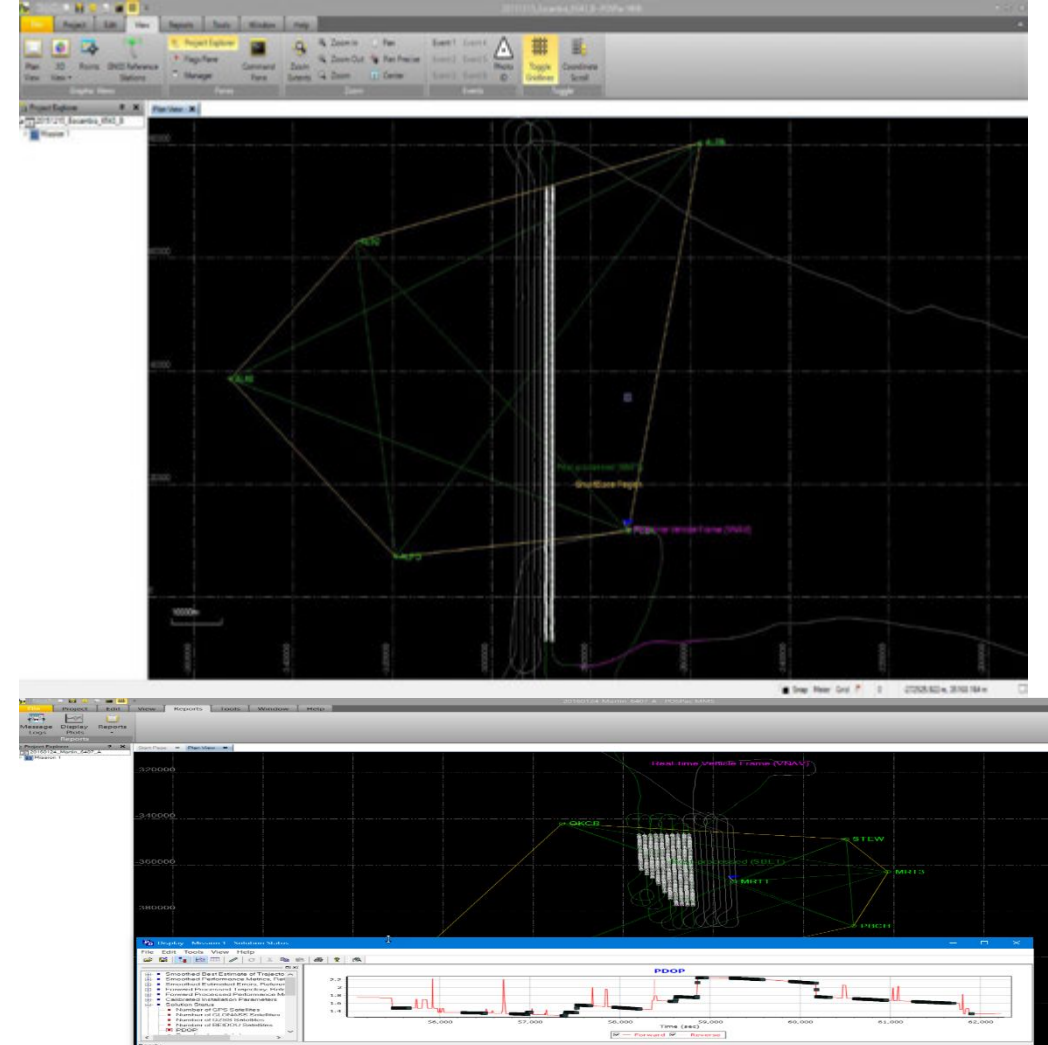
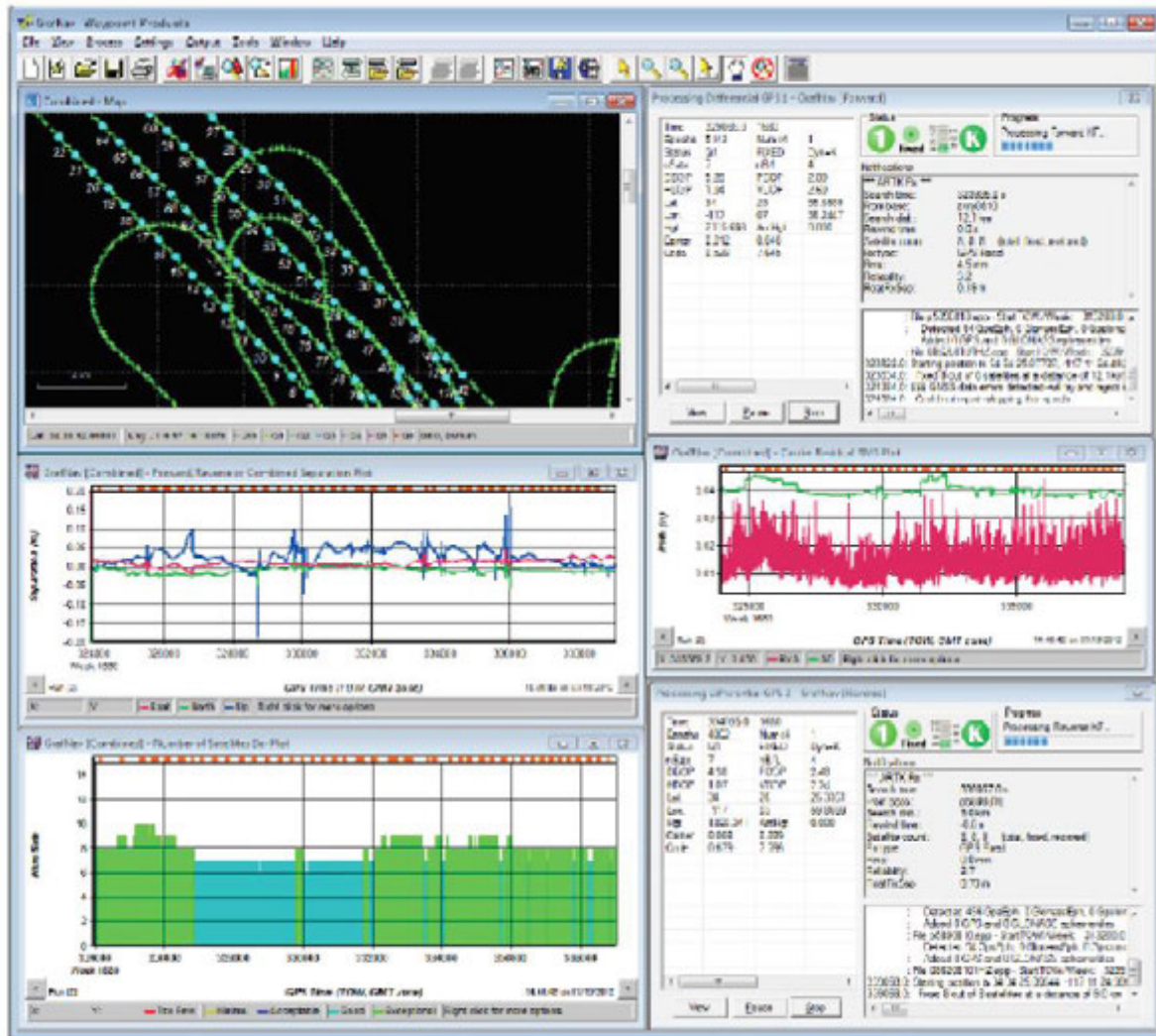
Create new Rinex Download or Manage existing Rinex jobs
Computation Service
Submit data for computation
FPRN Station Datasheets & Superseded Control
Individual Station Information for position at ARP

Antenna Reference Points (ARP)

<http://www.fdot.gov/geospatial/fprn.shtm>



Novatel - Inertial Explorer & Applanix – PosPAC - A Priori



- Exterior Orientation Computations

Aerial Photo Mission Workflow

Leica-Novatel Inertial Explorer SPAN

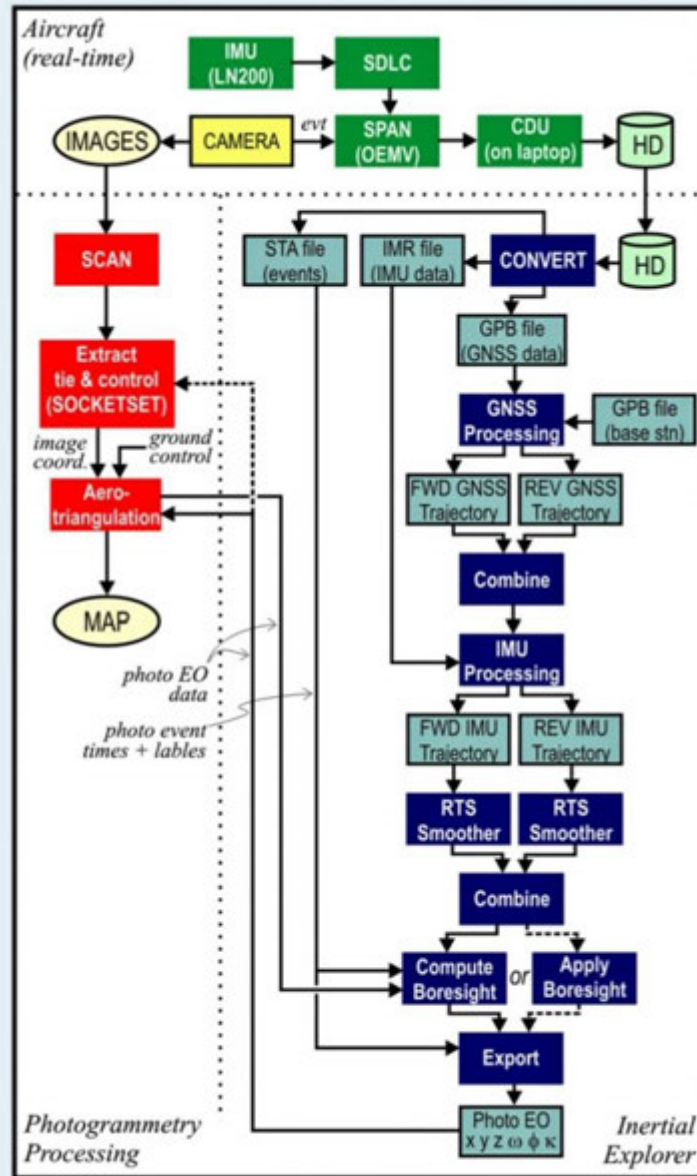


Figure 5: Workflow for Aerial Photo Mission Using Inertial Explorer and SPAN

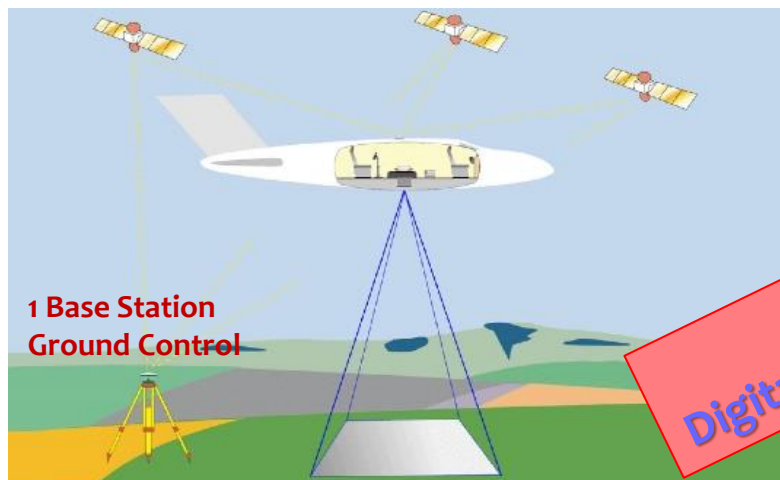
DRS in Photogrammetric Mapping and the FPRN

Standard with GNSS + IMU Inpho 10.7.4

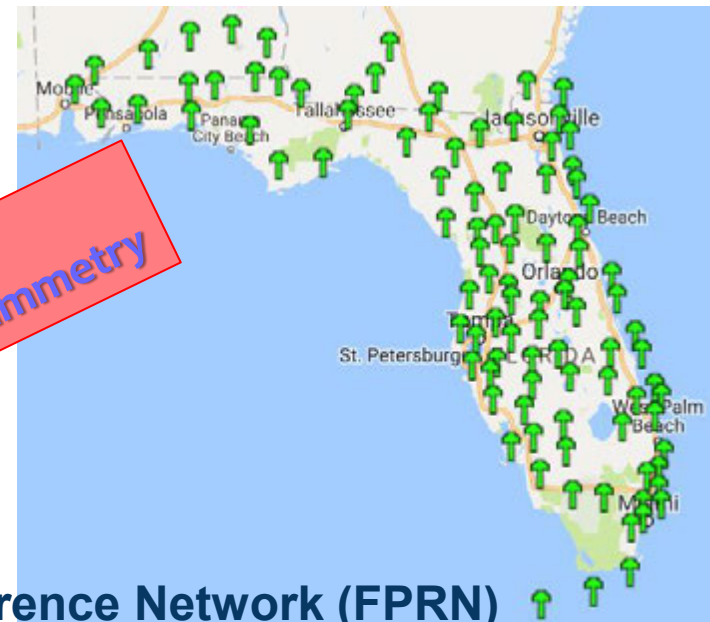
In theory **control points are not needed** when using GNSS/IMU data. In practice direct georeferencing without aerial triangulation is not accurate enough.

The poor accuracy of exterior orientation parameters derived from direct georeferencing is a result of GNSS projection center coordinates **not corrected for drifts and shifts**. Aerial triangulation can help to refine those positions.

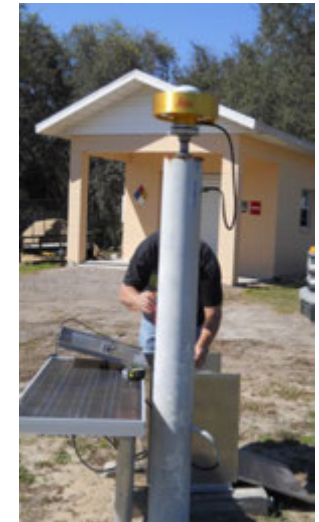
Just one ground control point is sufficient to determine **the shift** in GNSS/IMU measurements, to correct for **the drift**, requires at least one more control point.



The Holy Grail of
Digital Aerial Photogrammetry



Florida Permanent Reference Network (FPRN)



Camera Calibration

Leica RCD30 System Calibration Certificate

Sensor layout of tested system

The RGB CCD carries a BGGR Bayer pattern with overlapping spectral bands. The NIR sensor is a monochrome CCD. It is spectrally separated from RGB through a dichroitic beam splitter device. NIR pixels are 2x2 binned from 0.006 mm to 0.012 mm.

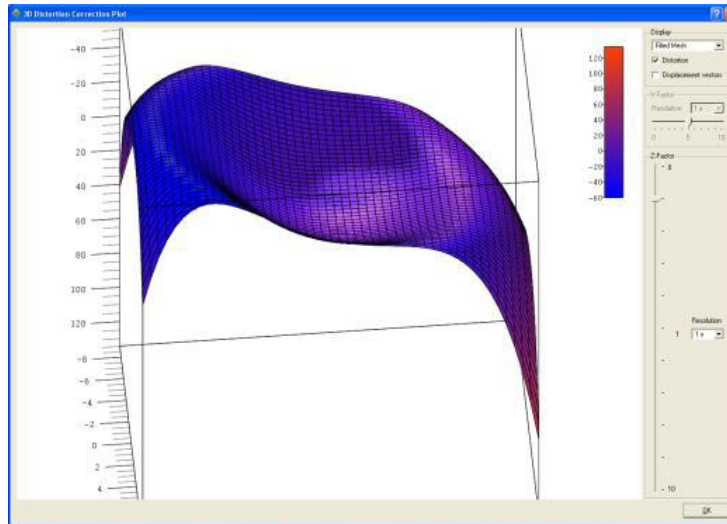
Sensor	Pixel size [mm]	Active rows	Active columns	Raw rows	Raw columns
RGB	0.0052	7752	10320	7788	10336
NIR	0.0120	3654	4478	3366	4500

Camera model of distortion free images

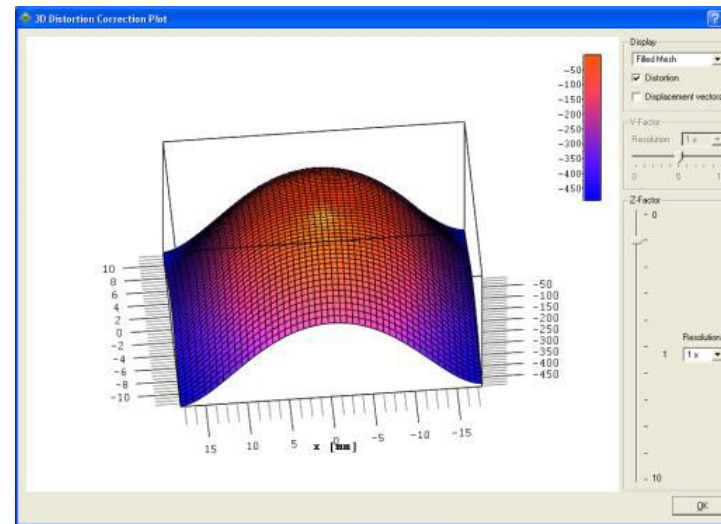
All factory calibration results contain fixed nominal focal lengths and zero principal point offsets.

Leica FramePro applies the grid to create distortion-free images of nominal focal length and pixel size. NIR is interpolated to the resolution of RGB during this process.

Parameter	Value of distortion free images
c: focal length	53 mm
xP, yP: principal point (PPA)	Zero The PPA is the origin of the image coordinate system. It is located in the image center (row 3893.5, column 5167.5).
k0, k1, k2: radial symmetric distortion	Zero
p1, p2: decentering distortion	Zero
b1, b2: non-orthogonality	Zero
Pixel size (height and width)	0.0052 mm for RGB and 0.006 mm for NIR
Image rows	7788
Image columns	10336



Correction Grid or Distortion Coefficients
Needed non-symmetric lens distortion



Radial Distortion Table
sufficient for specially designed metric camera

Leica RCD30 Digital Camera Parameters

Common questions are:

What is the calibrated focal length?

What is the sensor size in pixels?

What is the pixel size?

The screenshot shows the 'Camera Parameters' window with the following sections:

- Camera Information:** Camera Label, Camera Serial No. (62027), Lens System Serial No. (50033), Lens System Article No. (785422).
- Installation Settings:** X [mm] (70.00000000), Y [mm] (50.00000000), Z [mm] (70.00000000), Omega [°] (0.00000000), Phi [°] (0.00000000), Kappa [°] (0.00000000), Z GPS [°] (0.00000000).
- Update Calibration File:** Geometric Calibration (RCD30_GEOMETRY_CAMERAHEAD-62027-A-777966_LENSYSTEM-50033---785422_DATETIME-20130418-124441.XML), Fall Off (RCD30_FALLOFF_ALL-LENSES_DATETIME-20110621-140020.XML), Sensor Data (RCD30_SENSORDATA_CAMERAHEAD-62027-A-777966_DATETIME-20130415-140744.XML), PRNU File (RCD30_PRNU_CAMERAHEAD-62027-A-777966_DATETIME-20130415-140348.RAW), DSNJ Files (RCD30_DSNJ_CameraHead-62027_DateTime-20130817-005132.raw).
- Update Misalignment:** Omega [°], Sigma Omega, Phi [°], Sigma Phi, Kappa [°], Sigma Kappa. Each has a value field and a delta field.
- Update Principal Point:** x [mm], Sigma x, y [mm], Sigma y. Each has a value field and a delta field.

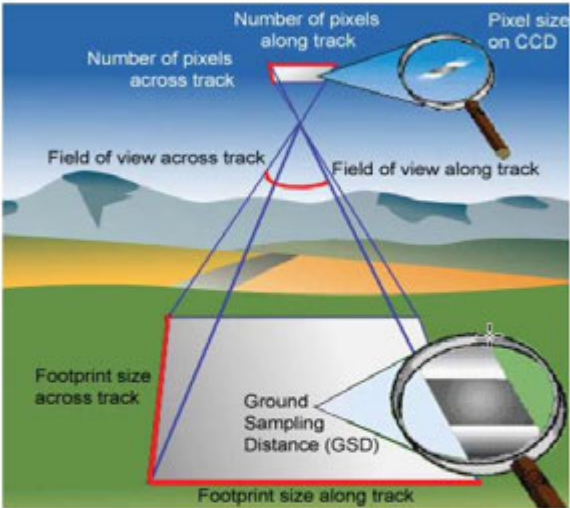
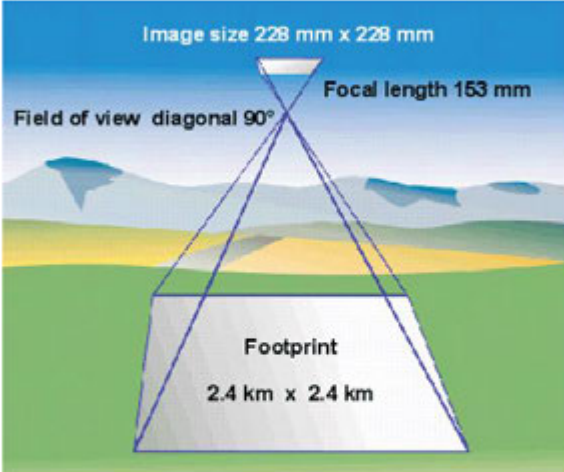
Buttons: Update, Add, Save, Exit.

RCD30 Sensor stores Camera Calibration in XML files

Photo Scale Vs GSD




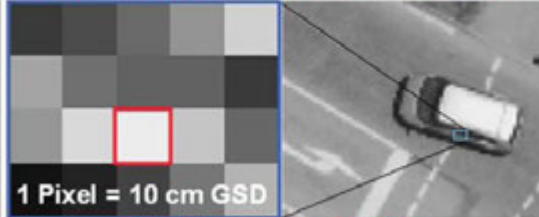
Terminology

Table 52. Terminology Explanation

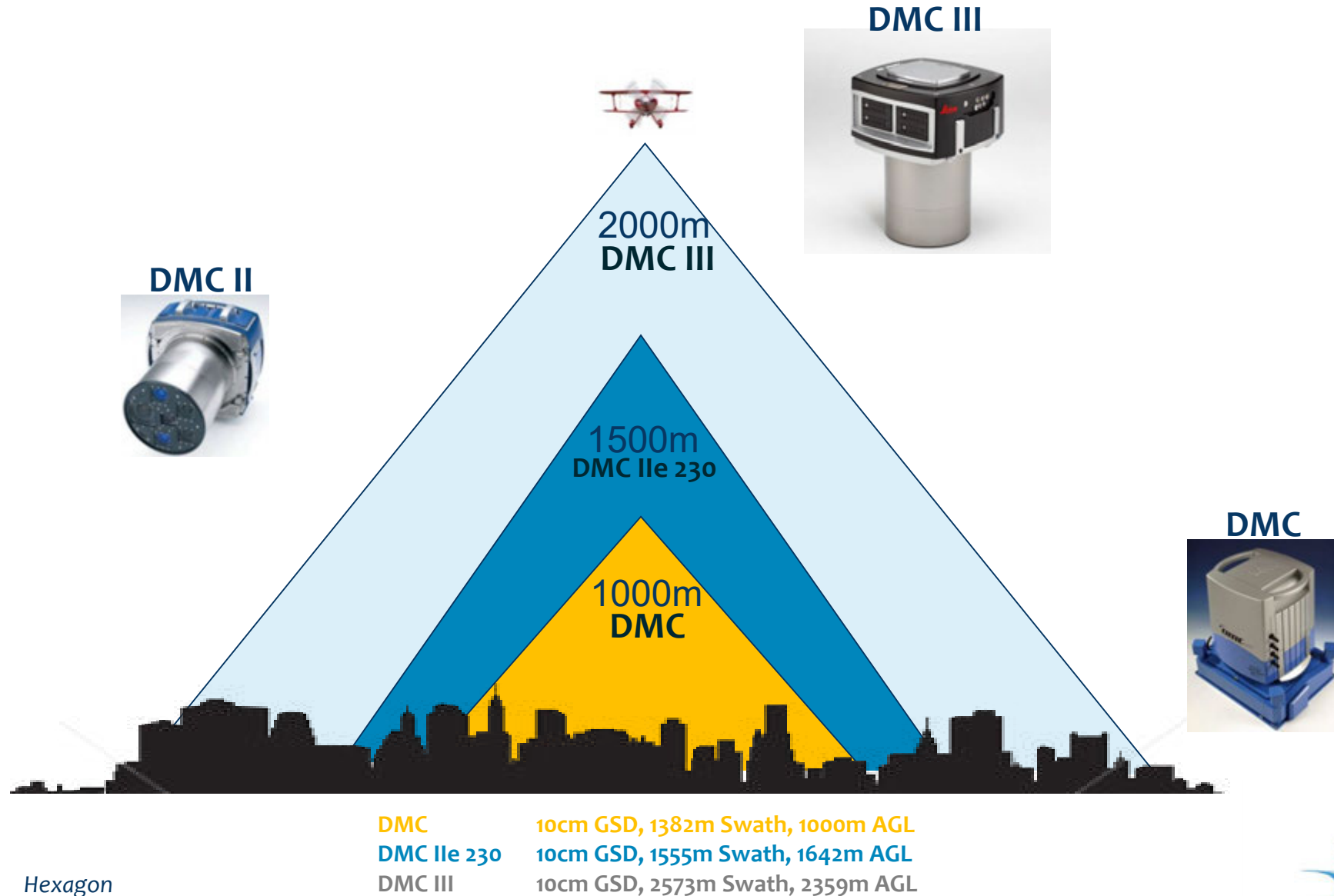
Airborne digital camera Leica RCD30	Film aerial camera RC30
 <p>Number of pixels along track</p> <p>Pixel size on CCD</p> <p>Number of pixels across track</p> <p>Field of view across track</p> <p>Field of view along track</p> <p>Footprint size across track</p> <p>Footprint size along track</p> <p>Ground Sampling Distance (GSD)</p>	 <p>Image size 228 mm x 228 mm</p> <p>Focal length 153 mm</p> <p>Field of view diagonal 90°</p> <p>Footprint</p> <p>2.4 km x 2.4 km</p> <p>Photo scale 1 : 10,500</p>
Central Perspective	Central Perspective

Terminology, such as focal length and its properties, are the same in the Leica RCD30 airborne digital sensor and the RC30 analog aerial camera. Other terms are derived differently. In other instances there are different words or terms used to represent items of a similar nature.

Table 54. Irrelevance of photo scale for direct digital images

Sensor with 6.5 μm CCD	Sensor with 12 μm CCD
 <p>Sensor data CCD: 12,000 pixels @ 6.5 μm Lens: $f = 63 \text{ mm}$, FOV 64°</p> <p>Flight data for 10cm GSD Flying height 965 m 'Photo' Scale 1 : 15,384 Swath 1,200 m</p>	 <p>Sensor data CCD: 12,000 pixels @ 12 μm Lens: $f = 120 \text{ mm}$, FOV 62°</p> <p>Flight data for 10cm GSD Flying height 1,000 m 'Photo' Scale 1 : 8,333 Swath 1,200 m</p>
Equal GSD at different image scales - even when the CCD pixel size is different	
<p>Digital image 12,000 pixels across track</p>  <p>1 Pixel = 10 cm GSD</p> <p>Swath on ground 1200 m</p>	<p>Digital image 12,000 pixels across track</p>  <p>1 Pixel = 10 cm GSD</p> <p>Swath on ground 1200 m</p>

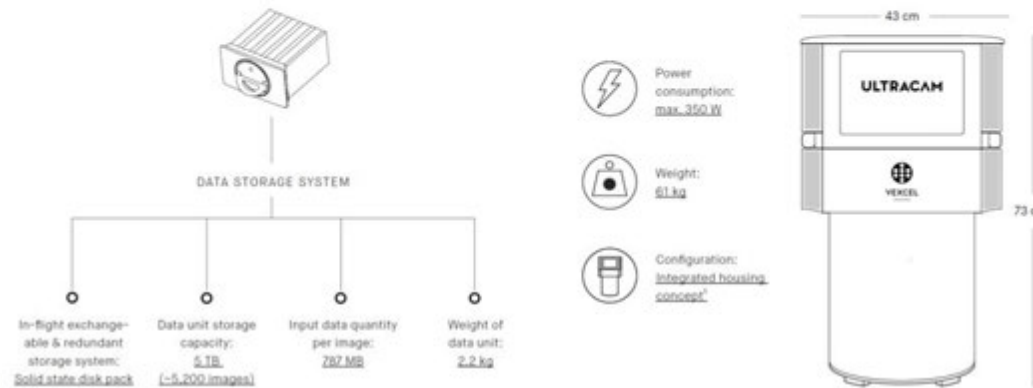
Zeiss DMC to DMC III - Evolution of Productivity



Vexcel UltraCAM

SENSOR SYSTEM

PAN image size	17,310 x 11,310 pixels	Imaging sensor	CCD
PAN physical pixel size	6.0 μ m	Shutter (longlife central leaf)	1/1000 to 1/64
Color capability (multi-spectral)	4 channels - R, G, B & NIR	Forward-motion compensation (FMC)	TDI controlled
Color image size	5,770 x 3,770 pixels	Maximum FMC capacity	50 pixels
Color physical pixel size	6.0 μ m	Frame rate (minimum inter-image interval)	1 frame per 1.35 seconds
Pansharpen ratio	1 : 3	Dynamic range	> 72 db
		Analog-to-digital-conversion at	14 bits



“When talking to data acquisition companies that are just now looking to transition from film to digital sensors, the topic of base-to-height ratio sometimes still comes up. This is often because some sensor manufacturers overemphasize b/h ratio to hide shortcomings of other factors in their camera design. While b/h ratio is not unimportant, it is not the only determining factor with respect to vertical height accuracy and has lost its significance in digital photogrammetry. There are other factors in the digital camera world that have an even greater impact.”

Jerry Skaw, Microsoft UltraCam Team – UltraCam Blog



UltraCam Calibration Laboratory: The three-dimensional calibration rig covers a horizontal field of 12 m.

Photogrammetry Versus LiDAR: Clearing the Air

Multi-Ray Photogrammetry *Microsoft* Requirements

■ Camera System

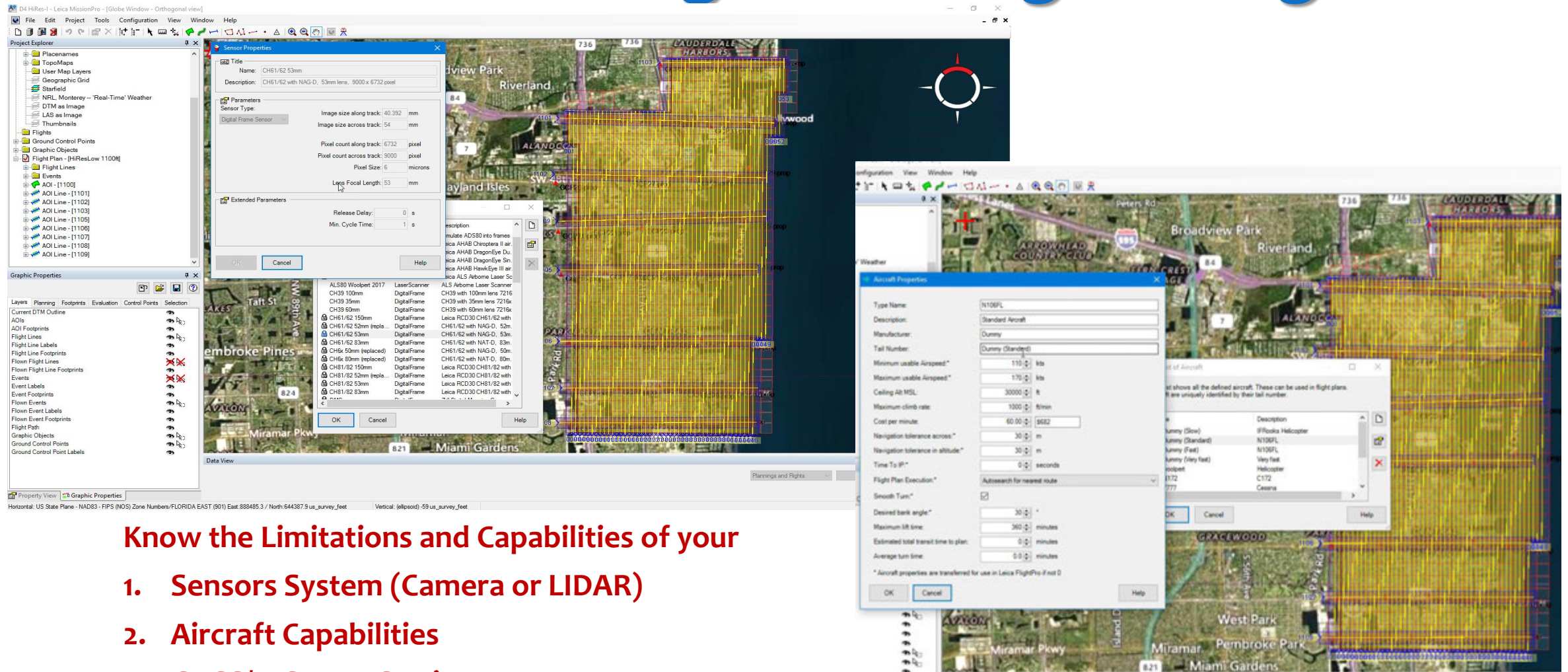
- ~~Good base/height ratio~~
- Capable to produce high frontlap frame images (footprint + max. frame rate)
- Geometric accurate and stable images (PAN, no Bayern pattern)
- High dynamic range PAN images (>7000 grey values, >> 12bit)
- Paralaxe free multi spectral images (syntopic exposure)

Alexander Wiechert, Managing Director
July 22, 2009



VEXCEL
IMAGING
a Microsoft company

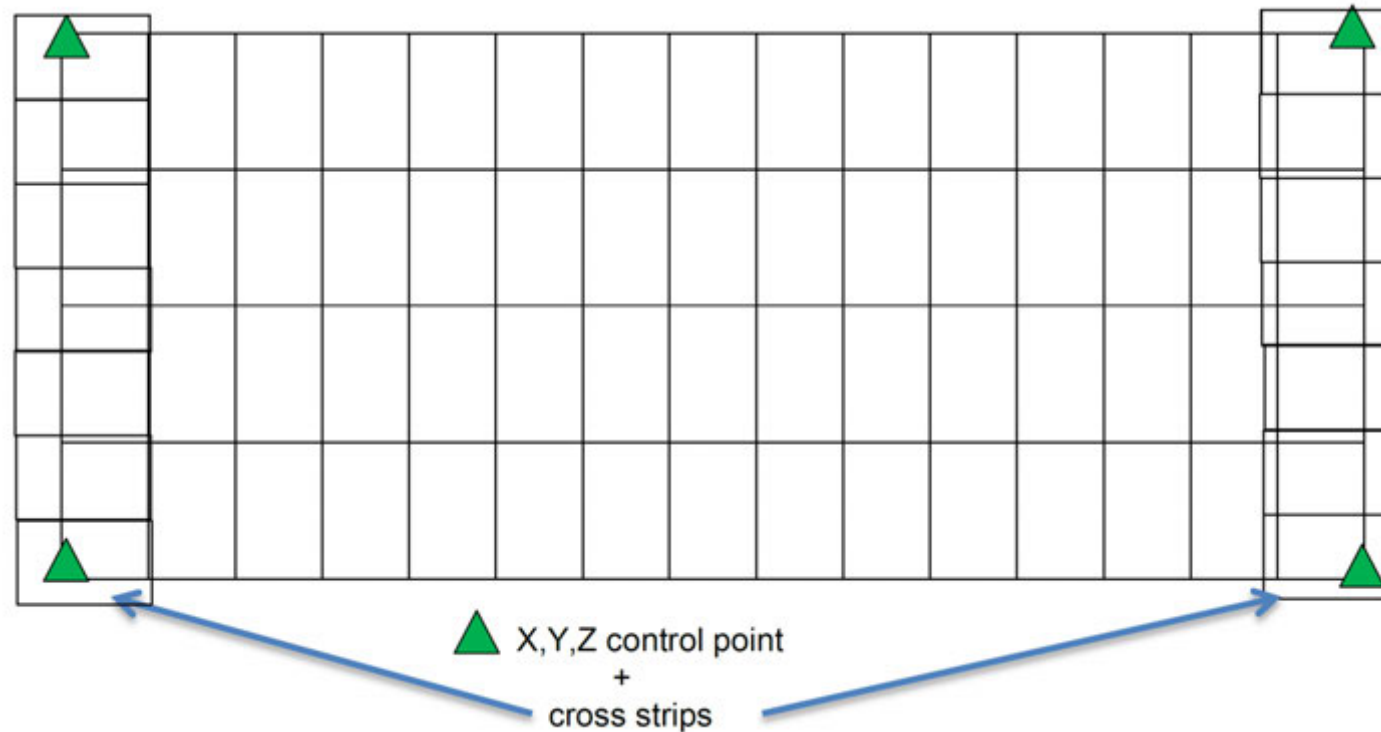
Mission Planning Matters get it Right!



Know the Limitations and Capabilities of your

- 1. Sensors System (Camera or LIDAR)**
- 2. Aircraft Capabilities**
- 3. GNSS/INS Base Station**
- 4. Optimum Satellite Configurations ...**

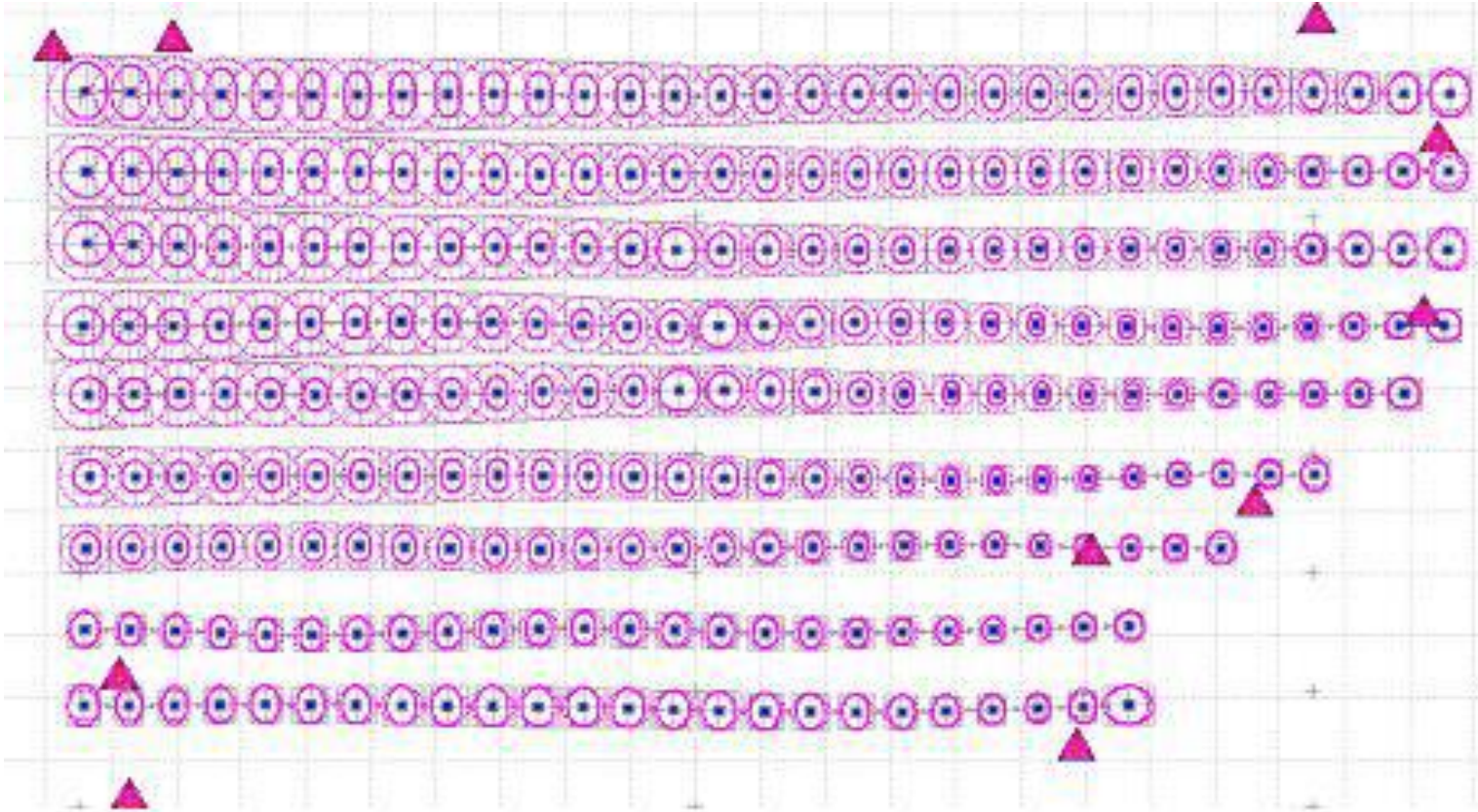
GNSS and Cross Strip Improves Block Stability



- GNSS additionally provides good approximations for the projection centers increasing the success rate in image matching and reducing processing times.
- The block stability is improved by GNSS in the triangulation run. Even if some photos are only sparsely connected to other photos the block remains stable.

By Inpho

GNSS/INS – Bad Drift and Shift Correction



Result is not acceptable!

**Shift and drift corrections
were not computed
successfully**

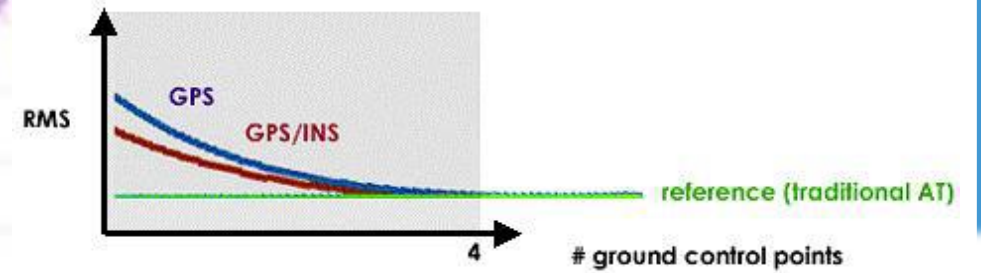
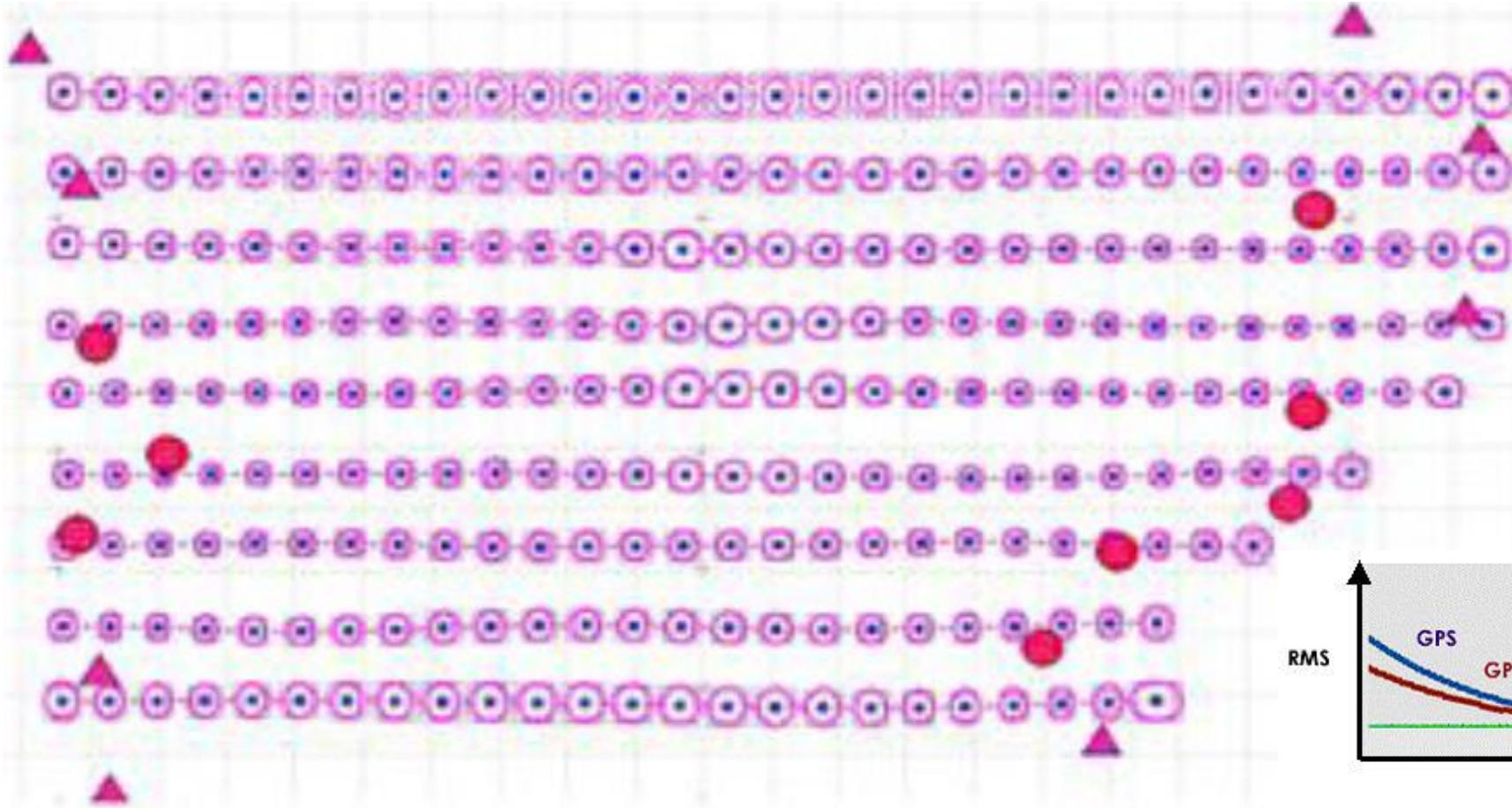
By Inpho

***“From a photogrammetric point of view, there is a great advantage
in the stability of a system with a minimum of moving parts”***

ASPRS Manual of Photogrammetry- Sixth Edition Sec 14.2.2

GNSS/INS – Good Drift and Shift Correction

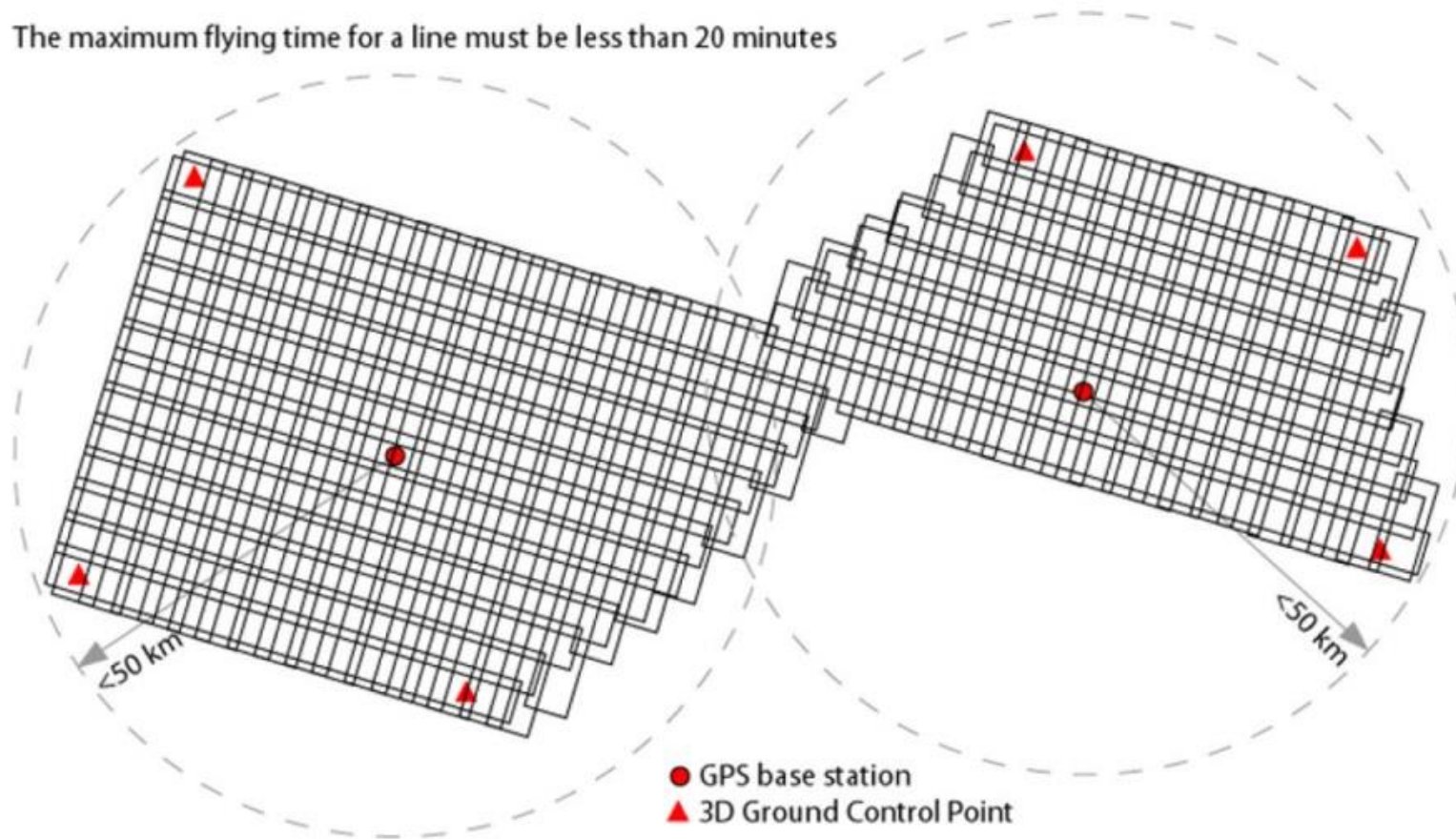
Good and reliable computation of exterior orientation parameters!



Block with cross strips for 3D Model extraction

Figure 87: Example Block with cross strips for 3D Model extraction

The maximum flying time for a line must be less than 20 minutes



Theoretically, the larger the distance from a control point, the larger the residuals

- Thus, the center is the best location for the single control point configuration. Base Station
- Control points in the block corners result in a better distribution of residuals and smaller residuals throughout the complete block.
- Check points should be used in the center of the block to detect any deformation.

Block with cross strips

Block with cross strips

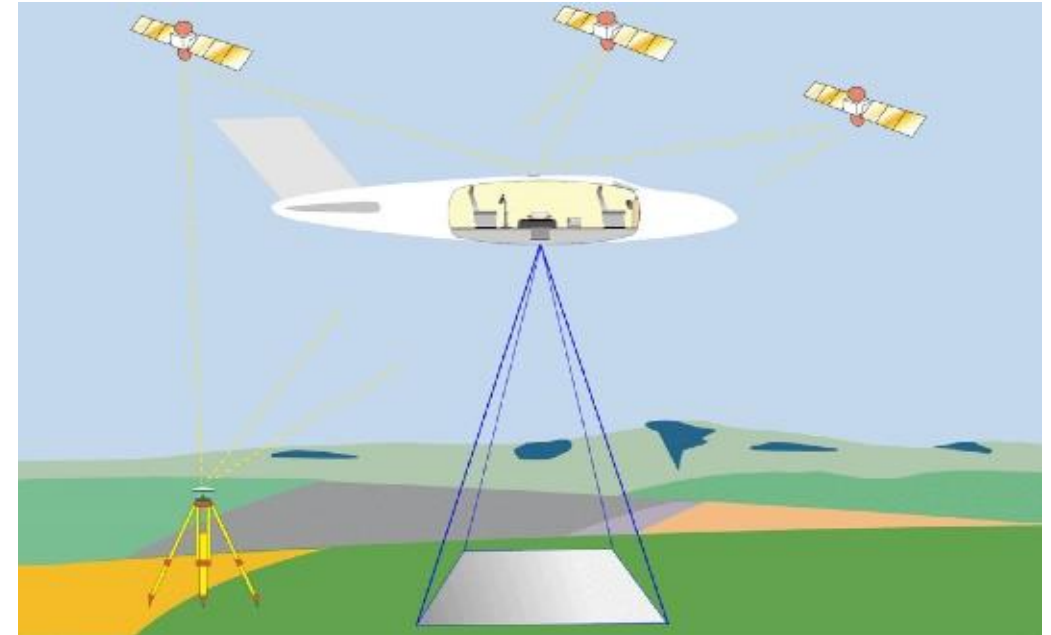
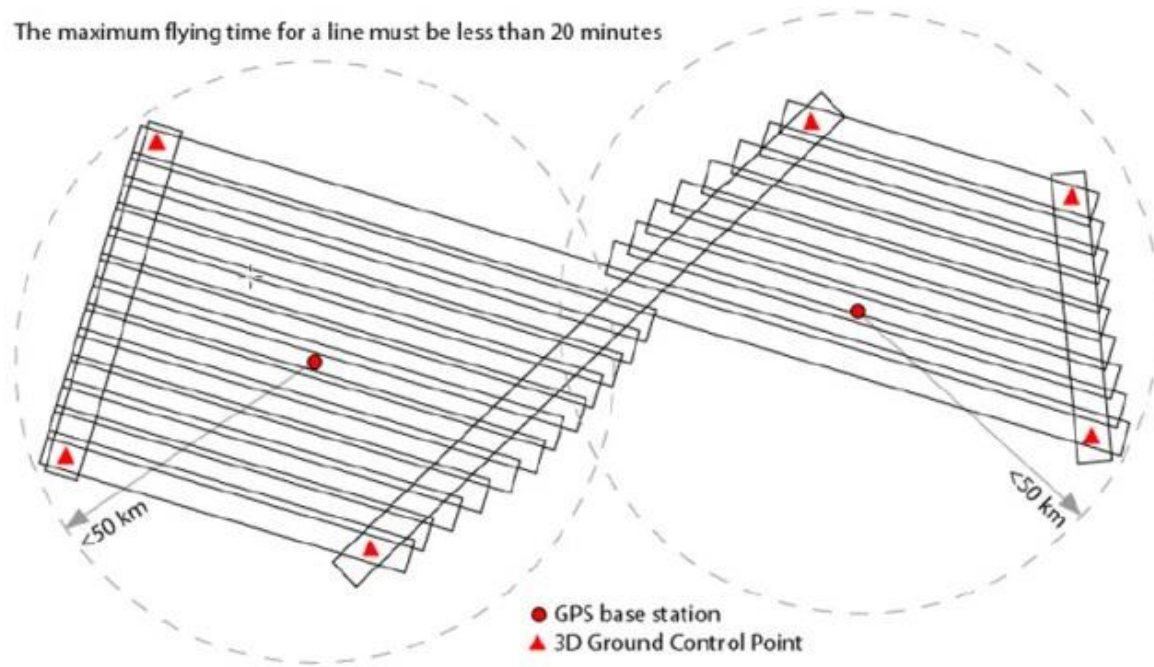
This arrangement is the preferred flight plan layout for applications like:

- Line Mapping. Stereo Feature extraction requires high pointing accuracy.
- 3D Model extraction. When the objective is to make all objects viewable from all sides.

The block can have any shape. At each corner a 3D-Ground Control Point should be placed such that it is covered by the flight line as well as by the cross strip. Examples are given in Figure 86 and Figure 87 below.

Figure 86: Example Block with cross strips for Line Mapping

The maximum flying time for a line must be less than 20 minutes



Leica RCD30 Aero-Triangulation Configurations

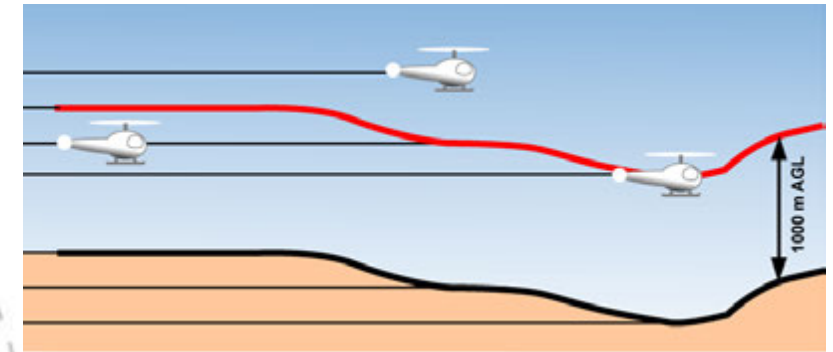
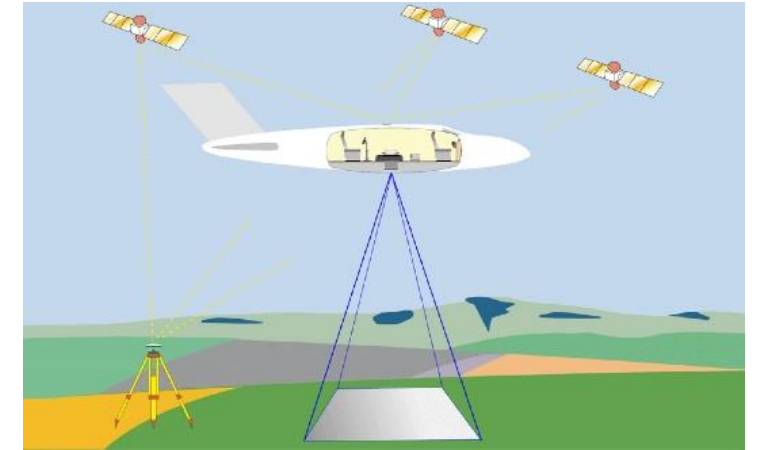
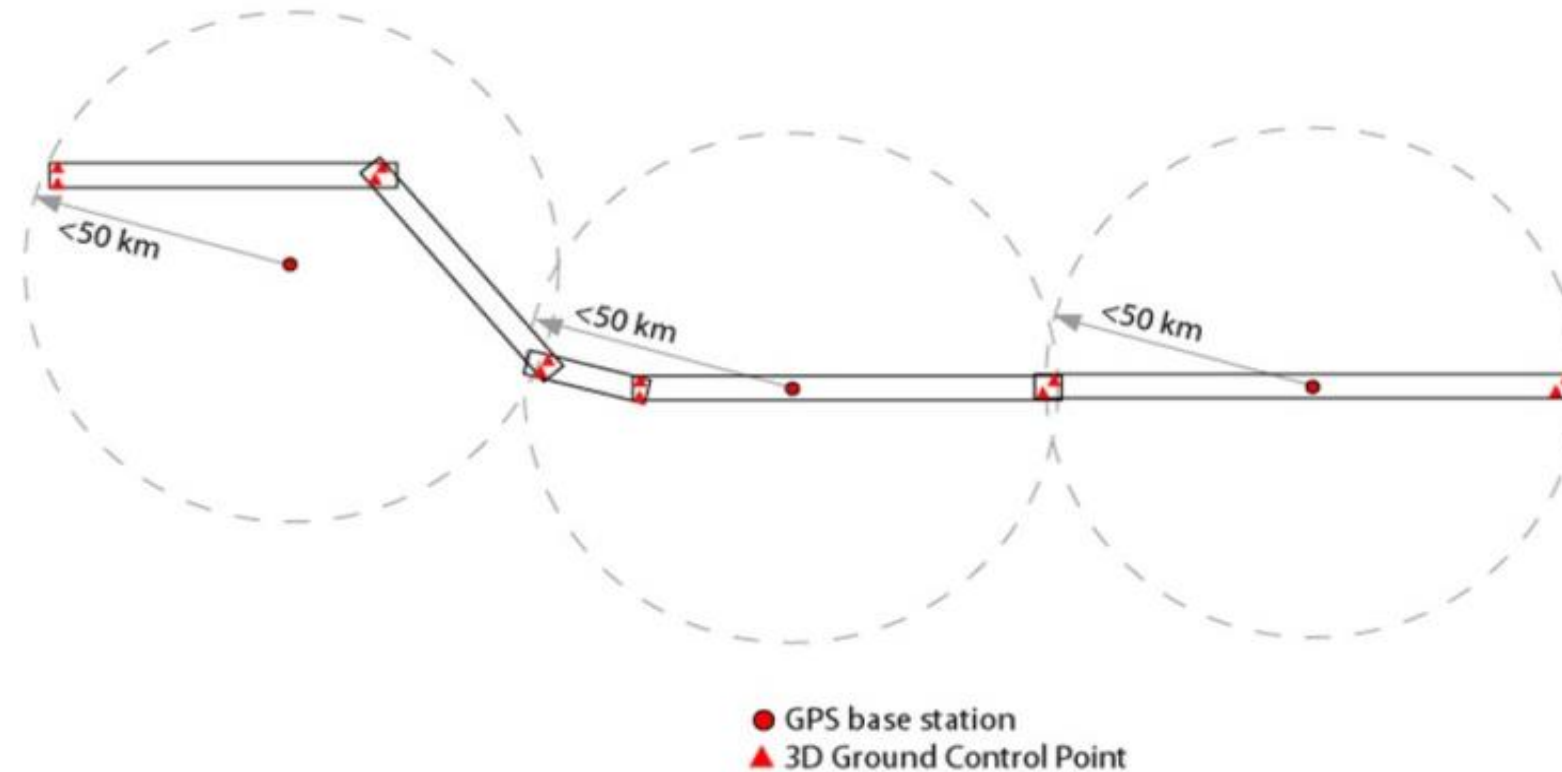
Corridor Mapping

Corridor mapping

At each corner of a strip of the corridor two 3D-Ground Control Points should be placed such that it is covered by the current flight line and by the flight line next in sequence. An example is given in Figure 88 below.

Figure 88: Example Corridor Mapping

The maximum flying time for a line must be less than 20 minutes



Leica RCD30 Aero-Triangulation Configurations

Block without cross strips

Block without cross strips

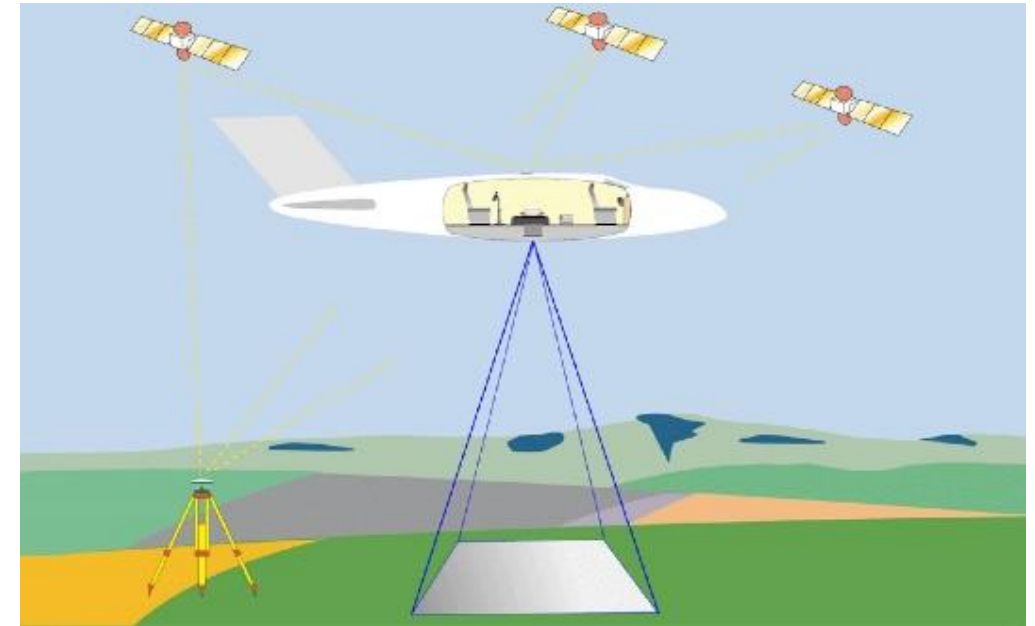
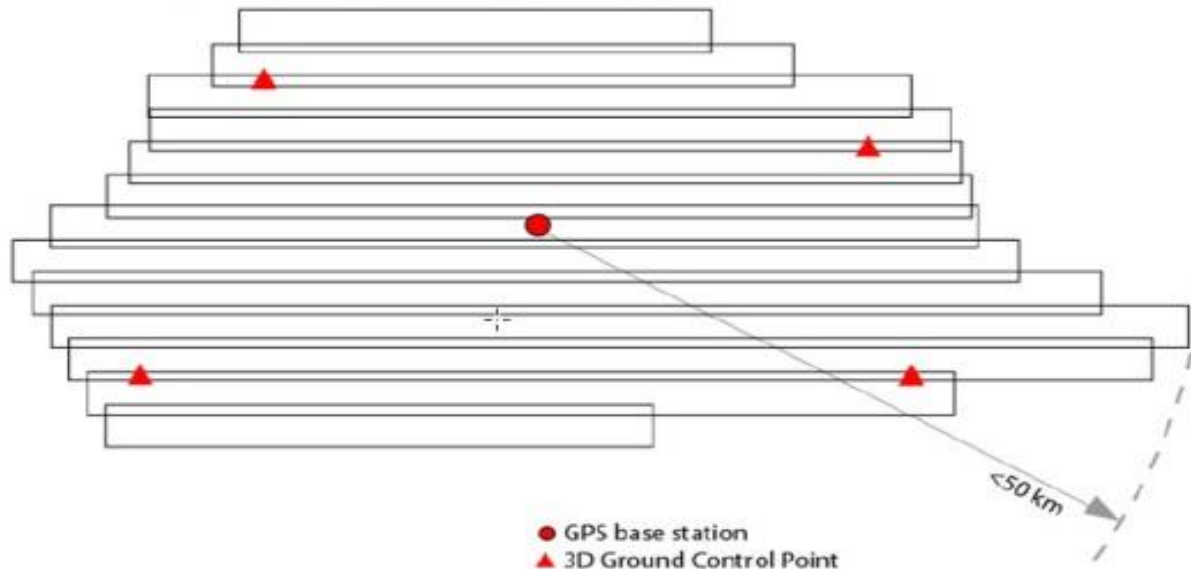
This arrangement is the preferred flight plan layout for applications like:

- True orthophotos
- Ground orthophotos
- DSM generation
- Remote sensing

The block can have any shape. Four 3D-Ground Control Points should be placed somewhere in the corner areas of the block. An example is given in Figure 85 below.

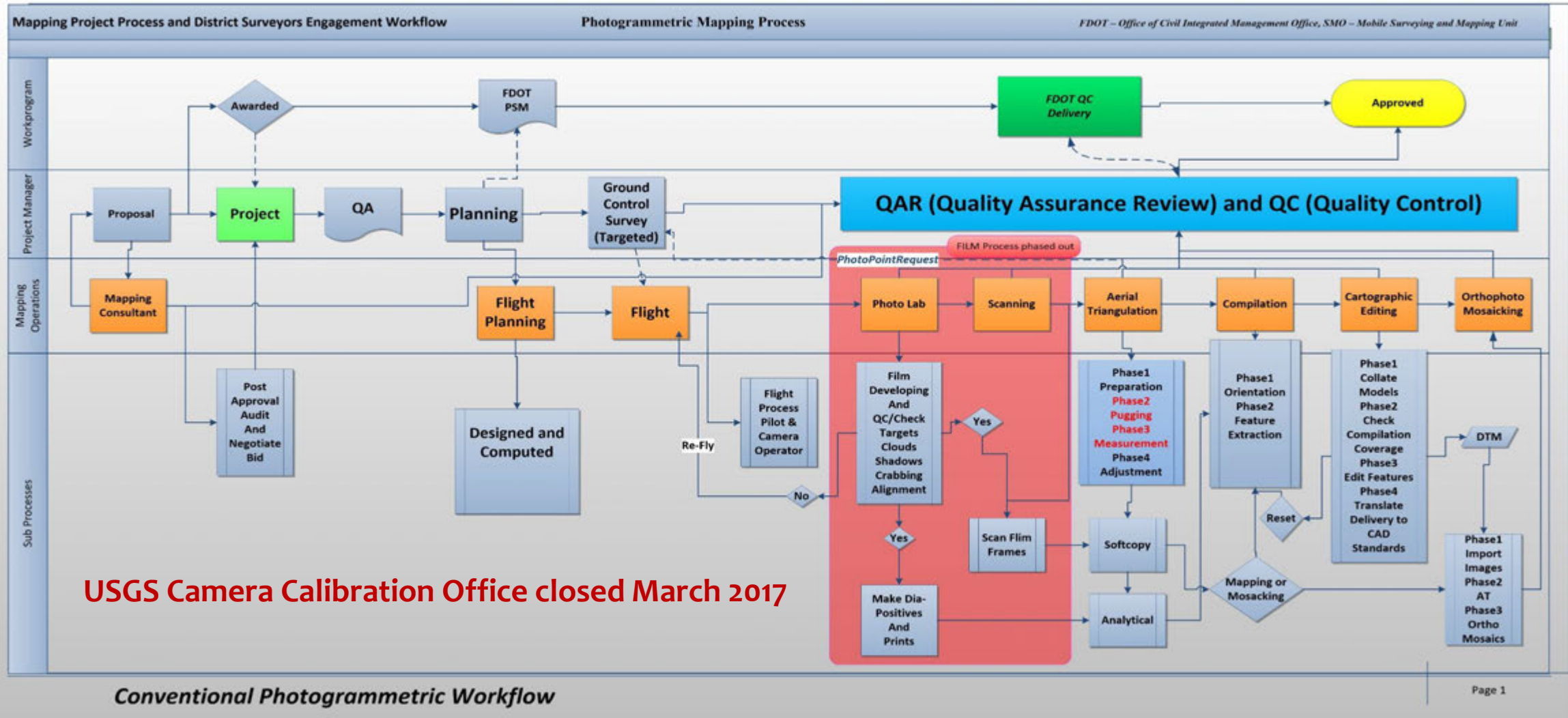
Figure 85: Example Block layout without cross strips

The maximum flying time for a line must be less than 20 minutes

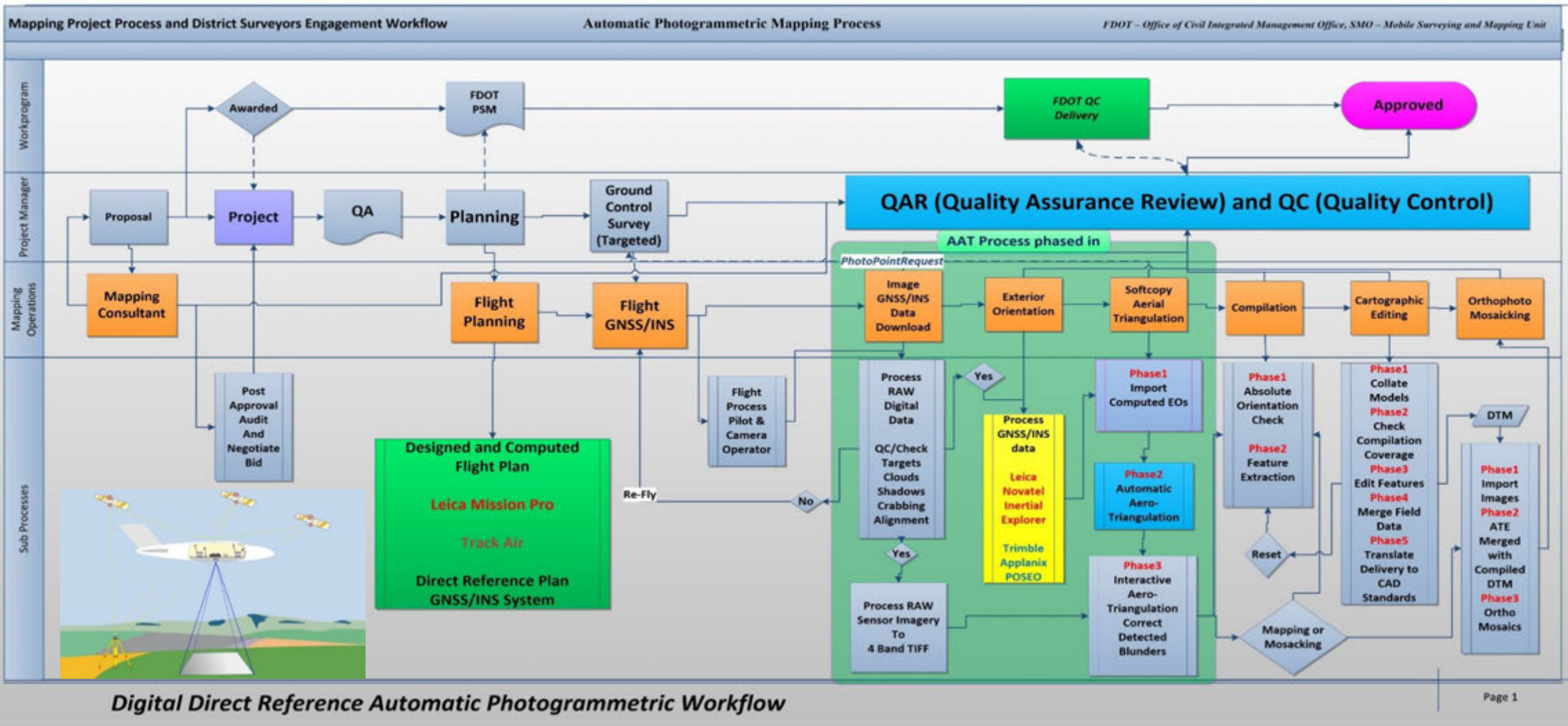


Leica RCD30 Aero-Triangulation Configurations

The Mapping Process for Conventional Photogrammetry



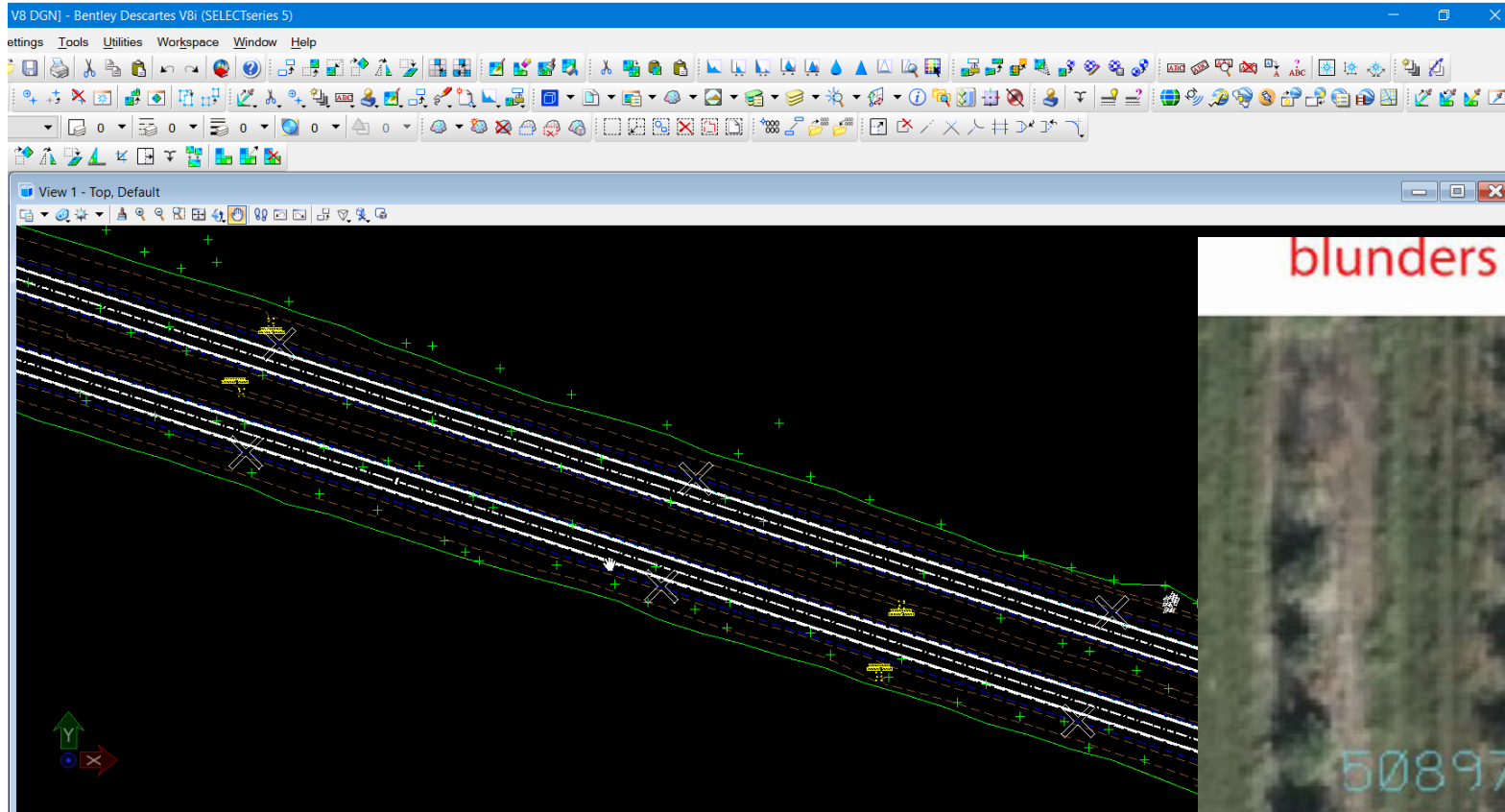
The Mapping Process for Digital Direct Reference (DRS)



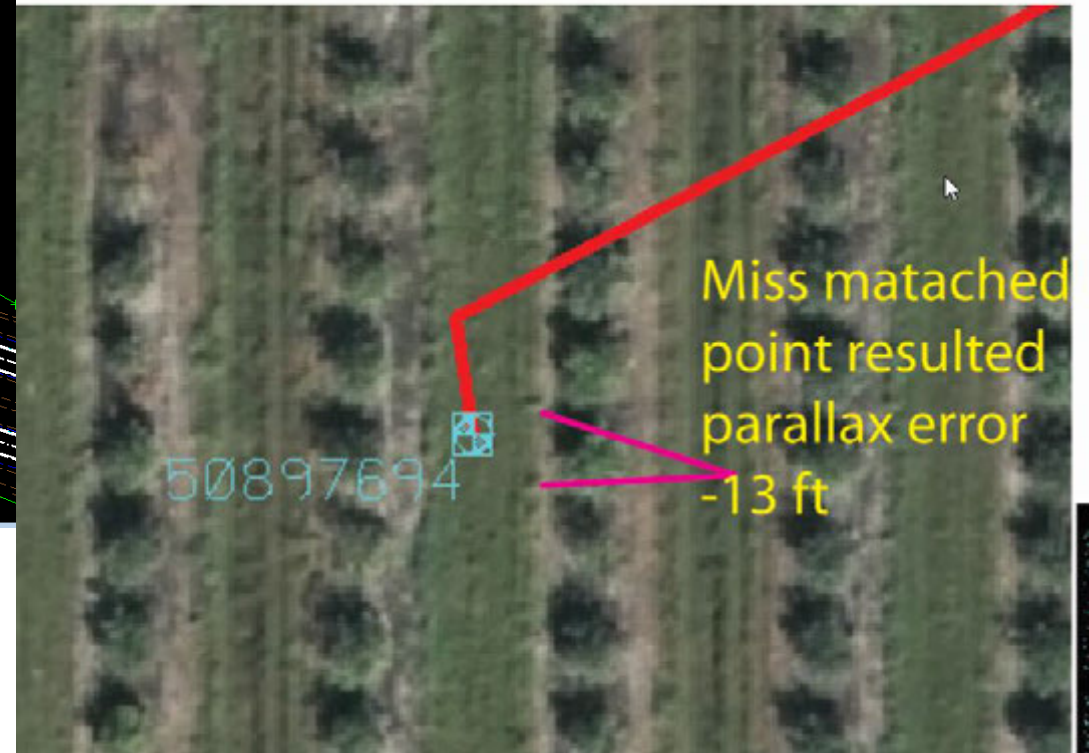
Proposed (Mobile Surveying and Mapping) MSM Data Delivery System for CIM (Civil Integrated Management)

Phase	Directory	Stages	Activities	Files	Data Dictionary
1	QAR	SOW	Store all scope of work documents	MSTS#SOW.doc, etc.	Documents citing the purpose of the project, Scope Of Work(SOW), Contract, etc.
			Journals, emails and memos.	MSTS#JNL.doc	Journal all decisions and activities prior to execution, include all emails
			Write-up of Proposed Approach and specific QAR document	MSTS#QAR.doc	Brief overview on the approach to the project, and QAR documentation relevant to the project
		AOI	Created limits of the project	MSTS#AOI.kml	A google earth KML file delineating the limits of the project, the Area Of Interest(AOI)
		Flight Planning	Created flight plan of the project	MSTS#FLP.kml	A google earth KML file showing proposed flight line,ground footprint, sensor events
		Recon	Created a location layout of GCPs	MSTS#GCP.kml	A google earth KML file showing proposed Ground Control Points
2	Collects	Boresight Calibration	Calibration Report of GNSS/INS/Sensor system	MSTS#BSC.txt	A ASCII text file output of sensor system boresight calibration, including the date executed every 3 months.
		Flight Execution	Download Direct referencing data GNSS/INS	MSTS#GNSS.xml	RAW Direct Reference System(GNSS/INS) data in XML or ASCII text format
		\RAWTIFF	Download AOI imagery collected in sub-folder \RAWTIFF	MSTS#EVENT#.TIFF	All imagery(Digital Aerial Photos) collected for the AOI in RAW TIFF format
		\RAWLAS	Download AOI imagery collected in sub-folder \RAWLAS	MSTS#SCAN#.LAS	All imagery (LIDAR) collected for the AOI in RAW LAS format
3	Registration	Sensor Orientation	Process the GNSS/INS data for Exterior Orientation	MSTS#EOS.csv	An ASCII comma delimited CSV text file- ImageName,Easting,Nothing,Elevation,Omega,Phi,Kappa,Roll,Pitch,Heading,RMS,X,Y,Z- Thus providing A Priori data to Aero-triangulation processing
			Process the GNSS/INS data for Trajectory Orientation	ASCII file of computations	
4	Processing	Aero-Triangulation	Run Automatic Bundle Adjustment and edit blunders	MSTS#ATEOS.csv	Post Aero-Adjustment Exterior Orientation -An ASCII comma delimited CSV text file- ImageName,Easting,Nothing,Elevation,Omega,Phi,Kappa,Roll,Pitch,Heading,RMS,X,Y,Z-
			N.B. The completed AT project can be delivered.	BINGO -MSTS#itera.dat	If using BINGO AT
				ISAT - MSTS#densified.txt	If using Intergraph ISAT
				SOCETSET GXP - MSTS#.gpf	If using BAE SOCET SET GXP
				Inpho Match AT- MSTS#itera.dat	If using Trimble Inpho Match-AT
				BLUH - MSTS#itera.dat	If using BLUH export BINGO itera.dat format
		Final Adjustment of LIDAR	Run final Adjustment on LIDAR data, filter noise and georef.	ASCII file of computations	Final Adjusted LAS point clouds
			Photos Georef. Coords final Adjustment	ASCII file of computations	Geotagged Photos on LIDAR trajectory
		Final Adjustment of Photos			
5	Products	Final AT Adjustment	Place Final AT Adjustment in this folder	MSTS#itera.dat -BINGO, PAT-B	Final AT format should be BINGO-itera.dat or PAT-B
		Final LIDAR Adjustment	Place Final LIDAR Adjustment in this folder	ASCII file of computations	Final ASCII file of LIDAR Adjustment
		Final Adjusted EOs	Place Final Final Adjusted EOs in this folder	MSTS#ATEOS.csv	Final EOs exported form Aero-Triangulation Software
		3D Topographic Survey	Place Final 3D Topographic Survey in this folder	MSTS#Survrd.dgn	Final Topographic Survey features extracted from Photogrammetry, LIDAR, and Field Surveys
		PSM AT Report	Place Final AT Report in this folder	MSTS#ATRPT.doc, non-scanned pdf(xml)	Professional AT survey report of the process, procedures and assessment. (N.B. No AT software print out)
		PSM GroundControl Report	Place Final Ground Control Report in this folder	MSTS#GCPRPT.doc,	Professional Field survey report of the process, procedures and assessment. (N.B. No AT software print out)
		\Orthos	Place Final Orthos in this sub_ folder \Orthos	MSTS#ORTHOTILE#.tiff	Final Orthophotography images in TIFF format with TFW sister files
		Final Adjustment of \LAS	Place Final Adjustment LAS point clouds. \LAS	MSTS#LASTILE#.LAS files.	Final Adjusted LAS point clouds
		Final Adjustment of \Photos	Place Final Photos taken on LIDAR Trajectory \Photos	MSTS#PHOTO#.jpg files.	Geotagged Photo on LIDAR trajectory
			Place Final Photos taken on LIDAR Trajectory \Photos	MSTS#TAGEO.csv	Exterior Orientation file for Photo taken on LIDAR trajectory
			Place Final Geospatial Metadata files	MSTS#PHOTO#.xml	FGDC/ISO metadata

Review AT results in Microstation



blunders not shown in the final solution



Ultra Edit – Text Editor ISAT Densified Controls

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1 begin control_points sx=0.1 sy=0.1 sz=0.1 pc=XYZ pt=CONTROL
2 14639442 980791.3496937762 684686.0064329652 189.9565091795694 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
3 14641274 981017.0357718545 683919.6846049401 163.842364257587 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
4 14641299 980804.6023358597 683844.8437805893 162.1085649692289 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
5 14749862 981841.9955795814 683014.7241192143 149.654635864915 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
6 14745516 982057.0819534571 684802.7482452799 184.912487101772 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
7 14745651 982184.2370866378 683951.8062397905 145.6418263212296 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
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15 14745698 982398.4007963456 683907.5308882631 148.679994246551 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
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18 14746277 978897.3493863898 683931.3244871888 167.0041761815536 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
19 14747026 979064.6373179563 684389.8611791706 156.5125497642547 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
20 14747152 979243.6301067931 684595.0956073857 180.7359626718665 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
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22 14746532 977294.4472242622 683935.8926357182 156.3714024456925 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
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24 14747312 977679.2248744245 684444.3679681 175.2422749153089 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
25 14748008 978515.6177438782 684783.9961236736 169.4296991650244 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
26 14748060 977634.1547573673 684979.5222474585 182.2042749805831 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
27 14637372 981668.2938386796 685173.8206778233 177.5322522105142 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
28 14742637 982452.6513564811 685465.2735930469 149.3719781343194 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
29 14637478 982197.3807144613 685410.7580580554 163.0364654668825 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
30 14644619 980855.3793545738 685875.4867253328 160.5153703775391 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
31 14631897 981516.3111954546 683824.8013040753 159.3214261948605 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
32 14626903 981010.9839001651 682788.15801826 148.9458993932362 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
33 14627062 981633.0658468802 682626.433688394 139.460882817574 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
34 14627310 981974.9332133646 682553.5823139806 152.3247112326998 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
35 14633340 981277.0323200621 683442.0503514946 160.4308638626631 /sx=0.1 /sz=0.1 /pc=XYZ /pt=CONTROL /desc= - Densified
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Request Software AT reports:
e.g.

ISAT - Densified Controls

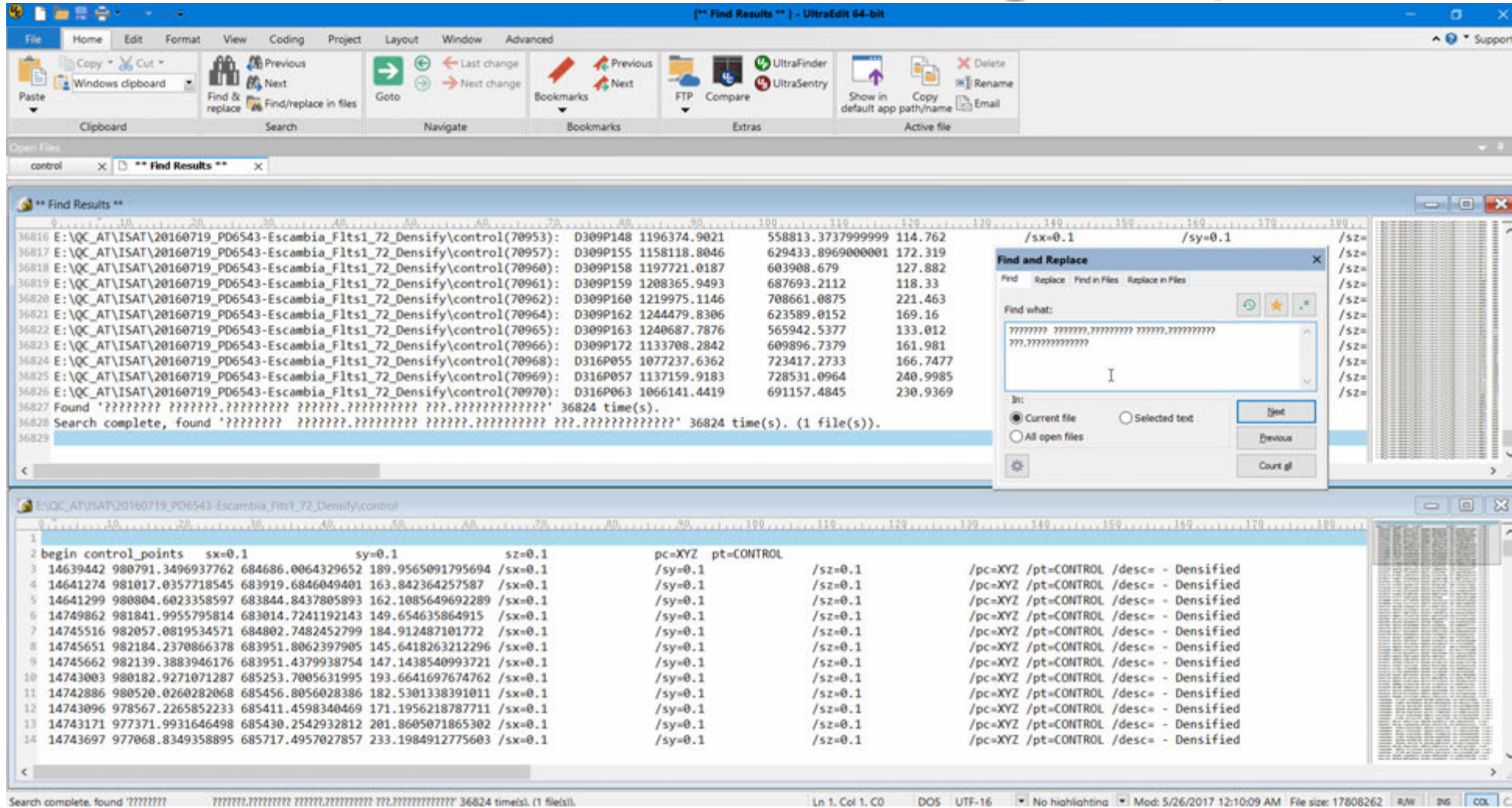
BINGO – itera.dat

Socet Set GXP – *.gpf file

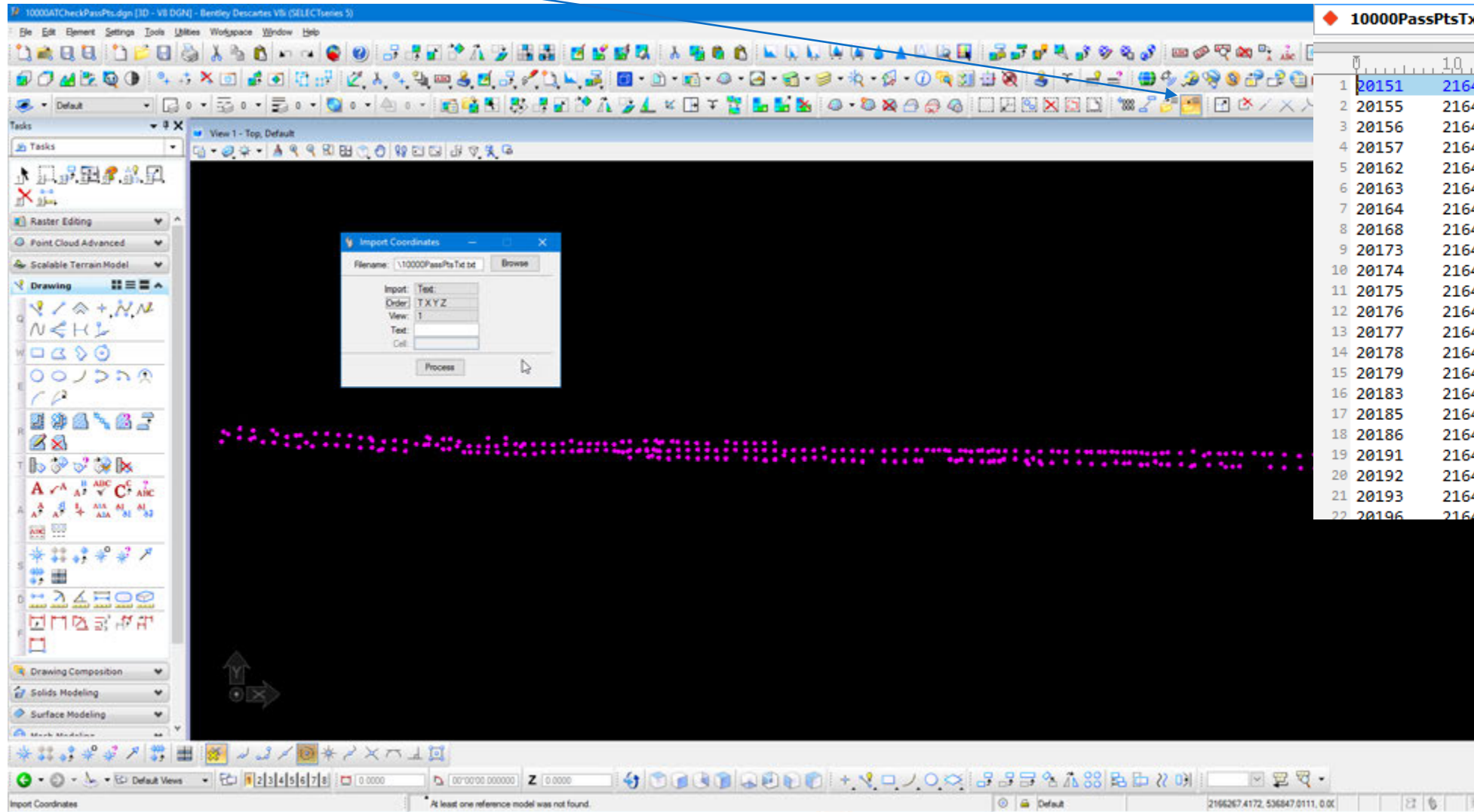
Inpho – PAT-B file *.ptb

Text Editor features need : Column Mode, Search By Regular Expression, and Results Output

Search ISAT Densified Controls Regular Expression

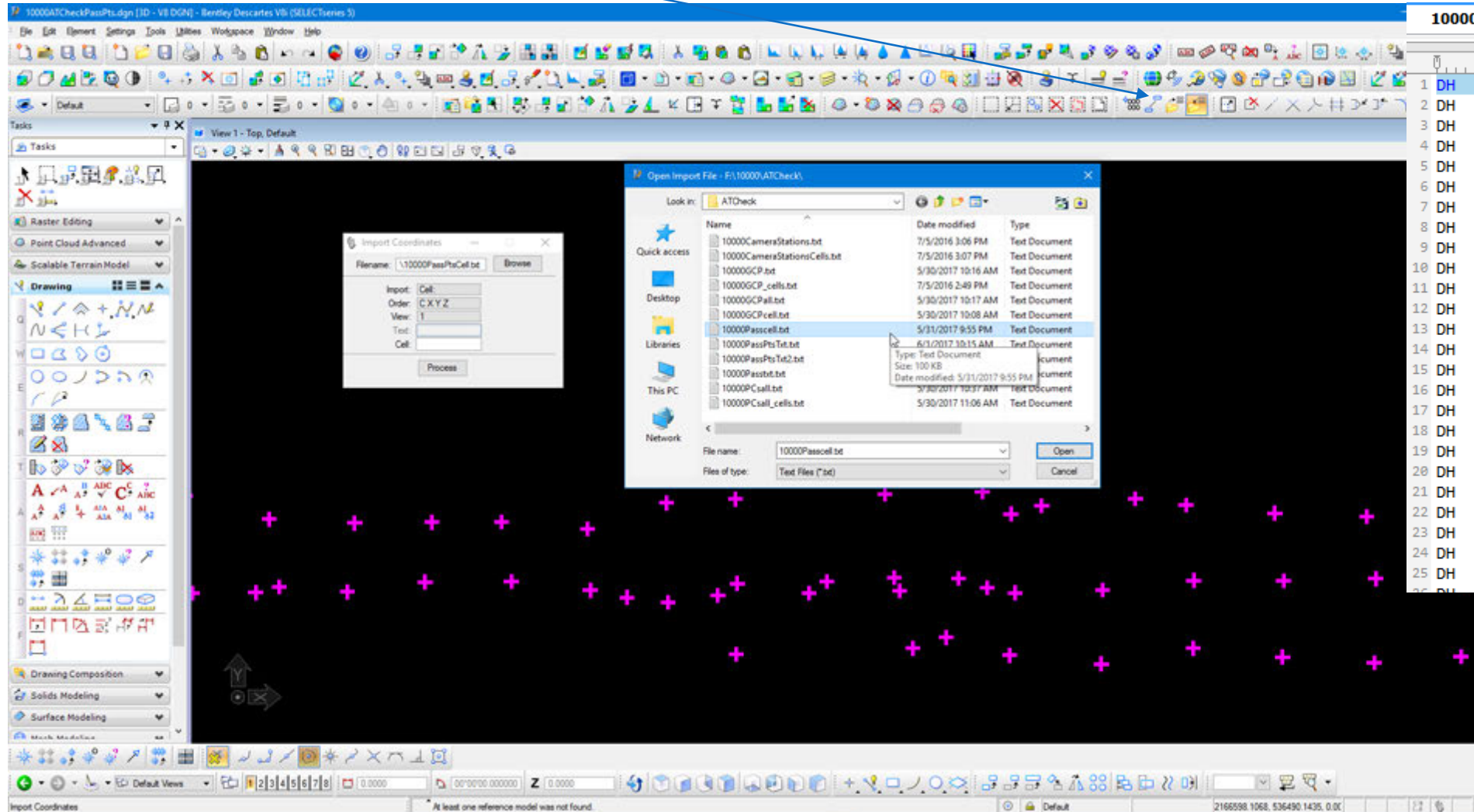


Import PassPt ID Text - Microstation TXYZ



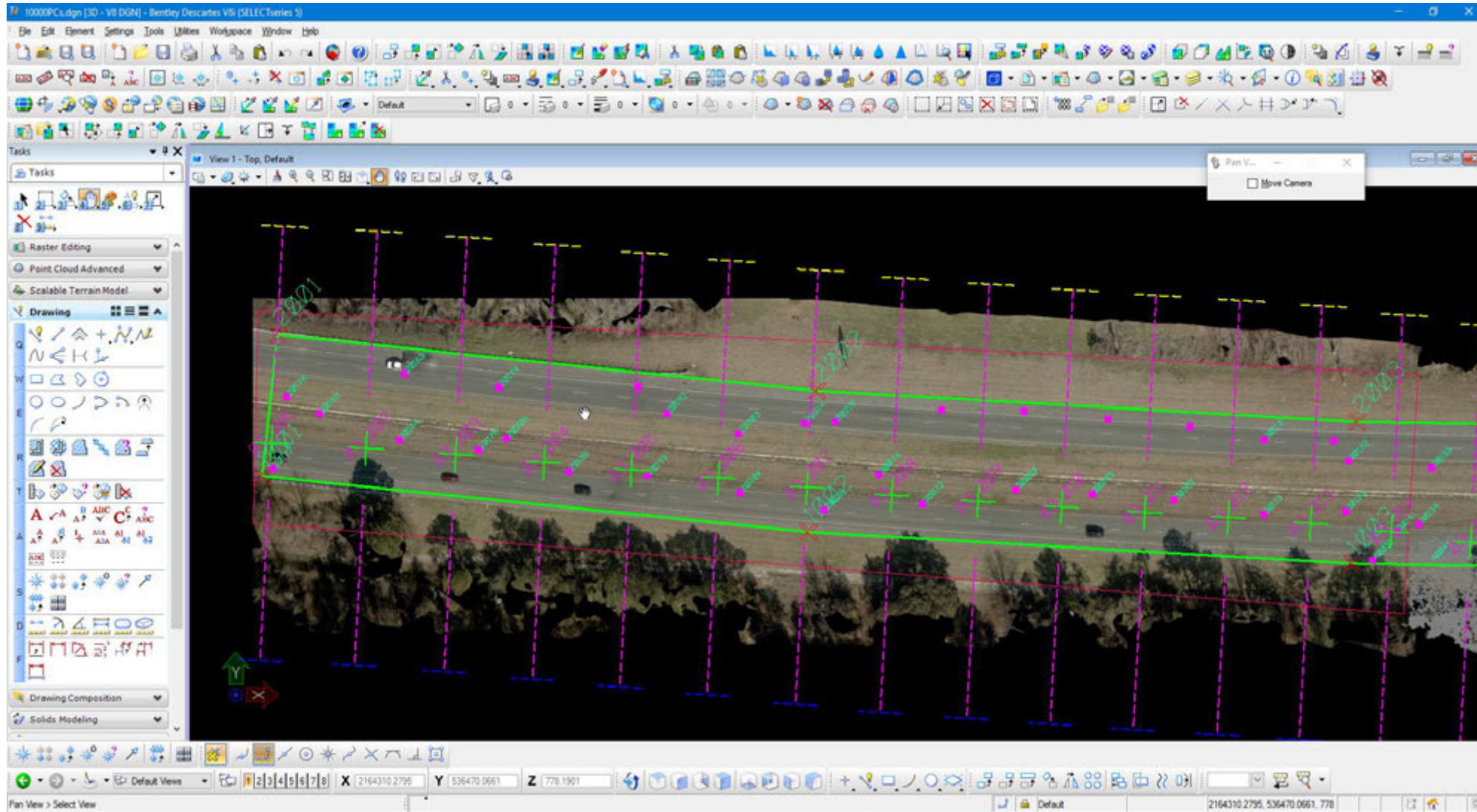
	10000PassPts.txt			
1	20151	2164106.72	536581.56	173.02
2	20155	2164066.13	536469.84	184.42
3	20156	2164047.44	536394.32	186.08
4	20157	2164041.60	536332.66	175.65
5	20162	2164063.17	536543.49	185.75
6	20163	2164144.28	536506.60	190.22
7	20164	2164139.58	536445.43	189.25
8	20168	2164010.59	536382.91	180.27
9	20173	2164189.53	536523.82	191.06
10	20174	2164231.15	536494.24	193.92
11	20175	2164212.43	536436.46	191.90
12	20176	2164035.88	536485.50	183.21
13	20177	2164023.30	536419.54	186.44
14	20178	2164162.88	536391.83	191.58
15	20179	2164198.96	536370.43	192.23
16	20183	2164126.41	536542.08	188.10
17	20185	2164295.52	536416.53	196.66
18	20186	2164276.38	536374.19	196.68
19	20191	2164401.76	536531.85	194.50
20	20192	2164385.86	536469.88	200.46
21	20193	2164367.71	536412.78	199.37
22	20196	2164316.88	536294.82	192.95

Import PassPt Cell - Microstation CXYZ



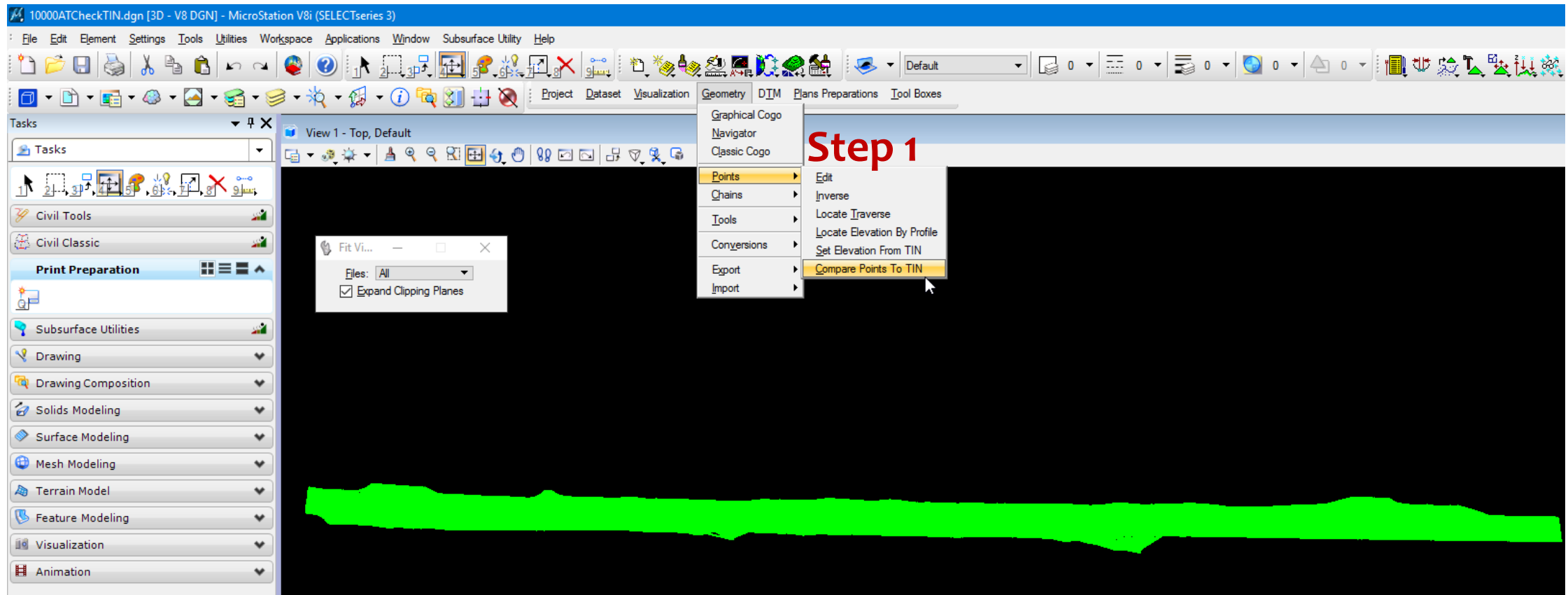
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4	DH	2164041.60	536332.66
5	DH	2164063.17	536543.49
6	DH	2164144.28	536506.60
7	DH	2164139.58	536445.43
8	DH	2164010.59	536382.91
9	DH	2164189.53	536523.82
10	DH	2164231.15	536494.24
11	DH	2164212.43	536436.46
12	DH	2164035.88	536485.50
13	DH	2164023.30	536419.54
14	DH	2164162.88	536391.83
15	DH	2164198.96	536370.43
16	DH	2164126.41	536542.08
17	DH	2164295.52	536416.53
18	DH	2164276.38	536374.19
19	DH	2164401.76	536531.85
20	DH	2164385.86	536469.88
21	DH	2164367.71	536412.78
22	DH	2164316.88	536294.82
23	DH	2164482.28	536532.63
24	DH	2164451.68	536451.32
25	DH	2164453.14	536397.23

AT Pass Points, (AOI)Area Of Interest, GCPs



Use Microstation XYZ to import - AT Camera Events, GCPs, Pass Points and Orthophotos for QC

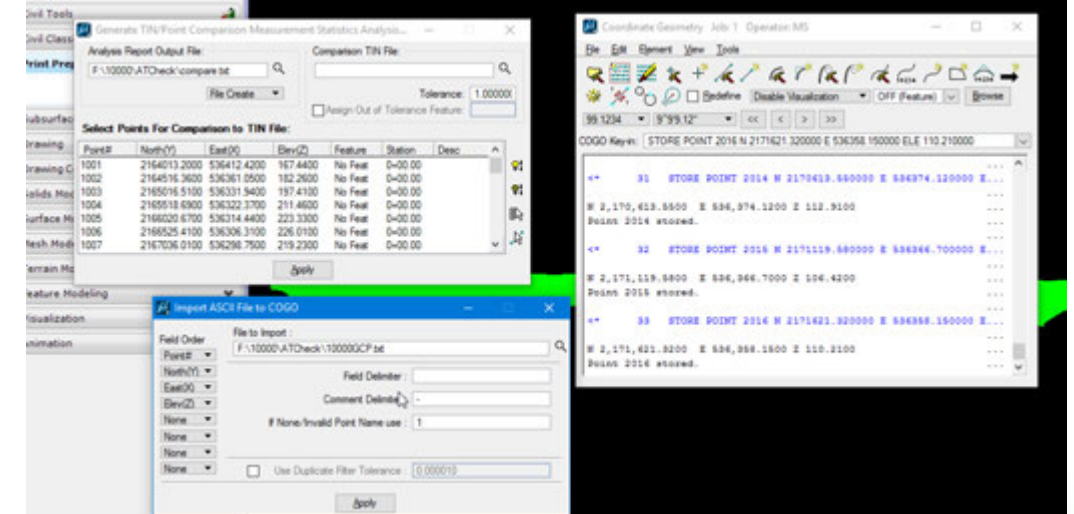
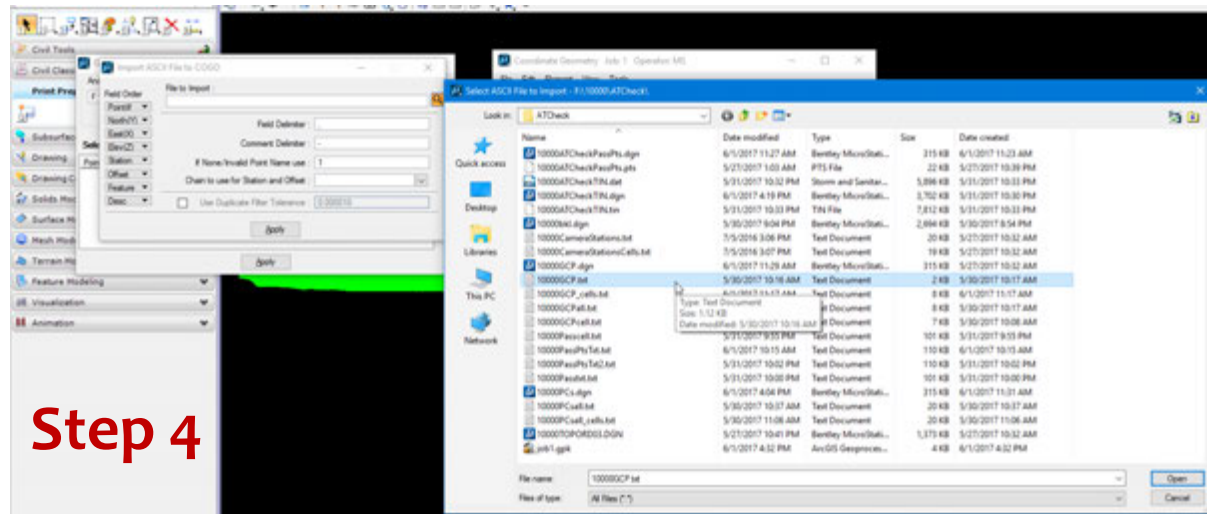
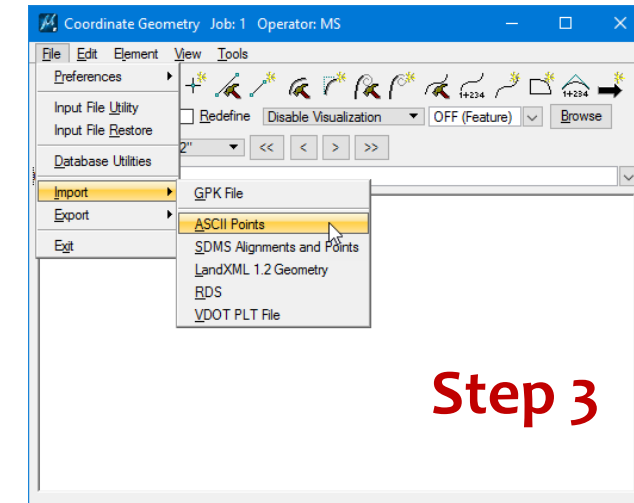
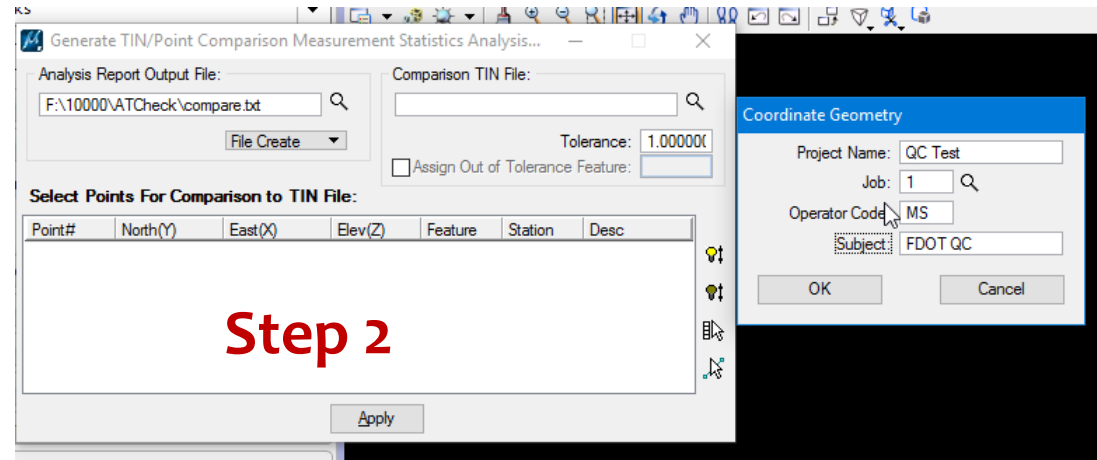
Bentley Geopak Civil/Survey – Surface Check



Check 3D Map Compilation/TIN against Ground Control Points, AT Pass Points NSSDA 95% confidence level.

Confirm that the map was compiled consistently as each compiler check controls as stereo models are loaded

Geopak Surface Check



Step 6

Coordinate Geometry Job: 1 Operator: MS

File Edit Element View Tools

Generate TIN/Point Comparison Measurement Statistics Analysis...

Analysis Report Output File: F:\10000\ATCheck\3DMapCompare.txt

Comparison TIN File: F:\10000\ATCheck\10000ATCheckTIN

Tolerance: .10

☐ Assign Out of Tolerance Feature:

Select Points For Comparison to TIN File:

Point#	North(Y)	East(X)	Elev(Z)	Feature	Station	Desc
1001	2164013.2000	536412.4200	167.4400	No Feat	0+00.00	
1002	2164516.3600	536361.0500	182.2600	No Feat	0+00.00	
1003	2165016.5100	536331.9400	197.4100	No Feat	0+00.00	
1004	2165518.6900	536322.3700	211.4600	No Feat	0+00.00	
1005	2166020.6700	536314.4400	223.3300	No Feat	0+00.00	
1006	2166525.4100	536306.3100	226.0100	No Feat	0+00.00	
1007	2167036.0100	536298.7500	219.2300	No Feat	0+00.00	

Apply

Geopak Surface Check-NSSDA

3DMapCompare.txt - Notepad

Point	Feature	COGO Elevation	TIN Elevation	Elev Diff	Location
1001	NOFEAT	167.4400	167.3911	0.0489	ABOVE
1002	NOFEAT	182.2600	182.1702	0.0898	ABOVE*
1003	NOFEAT	197.4100	197.3077	0.1023	ABOVE***
1004	NOFEAT	211.4600	211.3981	0.0619	ABOVE*
1005	NOFEAT	223.3300	223.2865	0.0435	ABOVE
1006	NOFEAT	226.0100	225.9387	0.0713	ABOVE*
1007	NOFEAT	219.2300	219.1715	0.0585	ABOVE*
1008	NOFEAT	204.9800	204.9003	0.0797	ABOVE*
1009	NOFEAT	189.5900	189.5180	0.0720	ABOVE*
1010	NOFEAT	172.8600	172.8123	0.0477	ABOVE
1011	NOFEAT	157.8500	157.7896	0.0604	ABOVE*
1012	NOFEAT	142.6400	142.6093	0.0307	ABOVE
1013	NOFEAT	127.6200	127.6074	0.0126	ABOVE
1014	NOFEAT	113.3300	113.2775	0.0525	ABOVE*
1015	NOFEAT	106.9500	106.8924	0.0576	ABOVE*
1016	NOFEAT	110.7000	110.6421	0.0579	ABOVE*
1017	NOFEAT	116.0000	115.9189	0.0811	ABOVE*
2001	NOFEAT	166.1500	166.0361	0.1139	ABOVE***
2002	NOFEAT	180.9200	180.8548	0.0652	ABOVE*
2003	NOFEAT	196.1200	195.9458	0.1742	ABOVE***
2004	NOFEAT	211.1500	211.1780	-0.0280	BELOW
2005	NOFEAT	223.2600	223.1590	0.1010	ABOVE***
2006	NOFEAT	225.9600	225.8800	0.1520	ABOVE***
2007	NOFEAT	219.0700	218.9993	0.0707	ABOVE*
2008	NOFEAT	204.6700	204.6061	0.0639	ABOVE*
2009	NOFEAT	189.2800	189.2253	0.0547	ABOVE*
2010	NOFEAT	172.7700	172.7030	0.0670	ABOVE*
2011	NOFEAT	157.6000	157.5058	0.0942	ABOVE*
2012	NOFEAT	142.5300	142.4207	0.1093	ABOVE***
2013	NOFEAT	127.4100	127.2343	0.1757	ABOVE***
2014	NOFEAT	112.9100	112.8184	0.0916	ABOVE*
2015	NOFEAT	106.4200	106.3441	0.0759	ABOVE*
2016	NOFEAT	110.2100	110.1277	0.0823	ABOVE*

The Sum of (Elev Diff)Squared = 0.2406
 The Ave of (Elev Diff)Squared = 0.0073
 The Root Mean Square Error is = 0.0854
 National Standard for Spatial Data Accuracy(NSSDA) is = 0.1673

Points PASS the 95% confidence test based on 1.96 Chi Square Value.

User defined Tolerance = 0.1000

Step 7

Check Control on Orthophotos Products

Control points editor

File Actions

Control points

Spatial Reference System (SRS): NAD83 / Florida North (NUS) (EPSG:2238) Set the SRS of all points to selected one

Name	Category	Check point	Given X	Given Y	Given Ellipsoidal height	Horizontal accuracy [m]	Vertical accuracy [m]	Estimated X	Estimated Y	Estimated Ellipsoidal height	RMS of reproj. error [px]	RMS of dist. to rays [m]	3D error [m]	3D horizontal error [m]	3D vertical error [m]
1013	Full	<input type="checkbox"/>	2170109.130	536253.560	127.620	0.010	0.010								
1014	Full	<input type="checkbox"/>	2170612.480	536245.630	113.330	0.010	0.010								
1015	Full	<input type="checkbox"/>	2171116.520	536238.760	106.950	0.010	0.010								
1016	Full	<input type="checkbox"/>	2171619.800	536230.300	110.700	0.010	0.010								
1017	Full	<input type="checkbox"/>	2172122.820	536222.530	116.000	0.010	0.010								
2001	Full	<input type="checkbox"/>	2164027.550	536542.550	166.150	0.010	0.010				8730.99	243.108			
2002	Full	<input type="checkbox"/>	2164523.960	536490.970	180.920	0.010	0.010								
2003	Full	<input type="checkbox"/>	2165021.310	536462.470	196.120	0.010	0.010								
2004	Full	<input type="checkbox"/>	2165518.090	536453.040	211.150	0.010	0.010								
2005	Full	<input type="checkbox"/>	2166019.980	536445.190	223.260	0.010	0.010								
2006	Full	<input type="checkbox"/>	2166528.180	536437.680	225.960	0.010	0.010								
2007	Full	<input type="checkbox"/>	2167038.370	536429.920	219.070	0.010	0.010								
2008	Full	<input type="checkbox"/>	2167540.050	536421.900	204.670	0.010	0.010								
2009	Full	<input type="checkbox"/>	2168050.200	536413.830	180.380	0.010	0.010								

Photos

Display photos: All Display points: All Display hints: Yes

0000_03_00 0000_03_00 0000_03_00 0000_03_00 0000_03_00 0000_03_00 0000_03_00 0000_03_00 0000_03_00 0000_03_01 0000_03_01 0000_03_01 0000_03_01 0000_03_01 0000_03_01 0000_03_01 0000_03_01 0000_03_01 0000_03_02 0000_03_02

Zoom: wheel ; ctrl ; +; - ; 0 | Move viewing area: click and drag | Add/Modify measurement: shift click | Quality=cached (Load original: 0)

Measurements

Measurements:

Image	x	y
...0000_03_001.i	1772.23	3764

Statistics

All control points:

- number of points: 34
- RMS of reproj. error: 8048.60 px
- RMS of dist. to rays: 242.668 m

Current photo:

- number of usable measurements: 2
- RMS of reproj. error: 8048.60 px
- RMS of dist. to rays: 242.668 m

What Went Wrong ?

- **poor source images:** grainy, low-resolution images, images that contain too little parallax, images that differ greatly in contrast and brightness (perhaps collected on different dates or under different circumstances);
- **poor georeference control:** control points with residuals many times greater than the cell size of the image; no control points on high-elevation features;
- **poor tie point correlation:** inability to place useful tie points in large featureless areas of the photos where even the human eye finds too little stereo information for 3D viewing;
- **too few tie points for DEM extraction:** blocky, low-resolution DEM results.

If you do not get impressive results on your first try, do not be discouraged. The DEM and orthophoto process is by nature very sensitive to the accuracy of input control values.



TNTmips
MicroImages

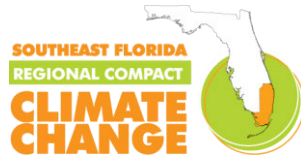
SOME OTHER CONTRIBUTING FACTORS

- Unstable System -to many moving parts
- Unstable computer systems - leaking memory
- Image Artifacts - Unstable power supplies
- Inconsistent boresight calibrations
- Flight Crabbing
- Extreme Tip and Tilt
- GNSS\INS shift and drift
- Inconsistent blunder detection
- Incomplete y-parallax elimination
- QC on final products

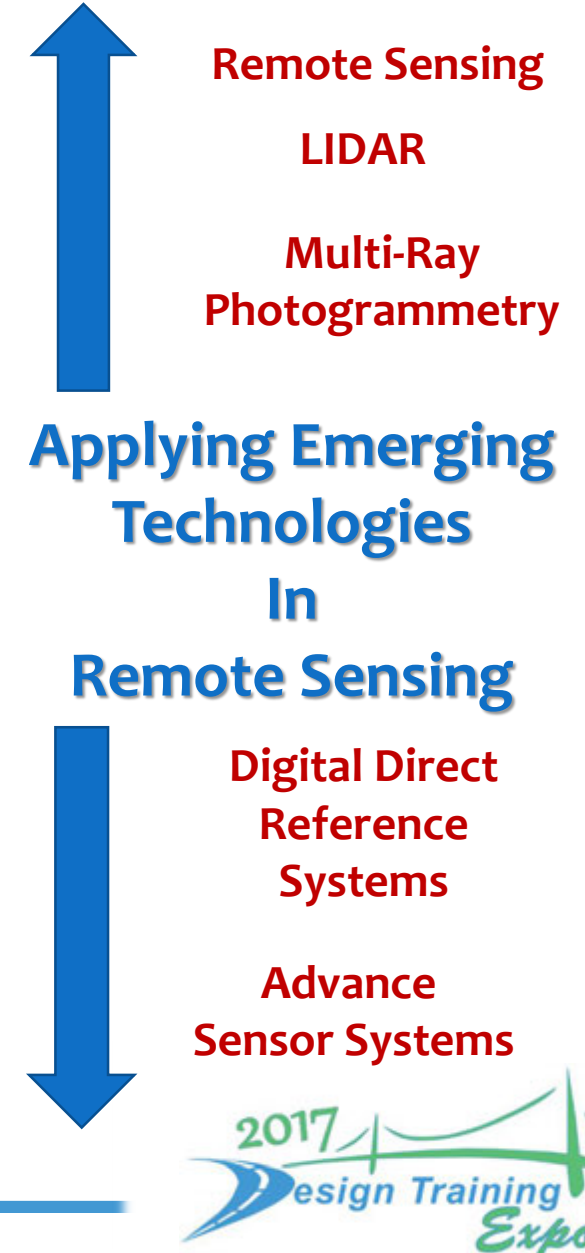
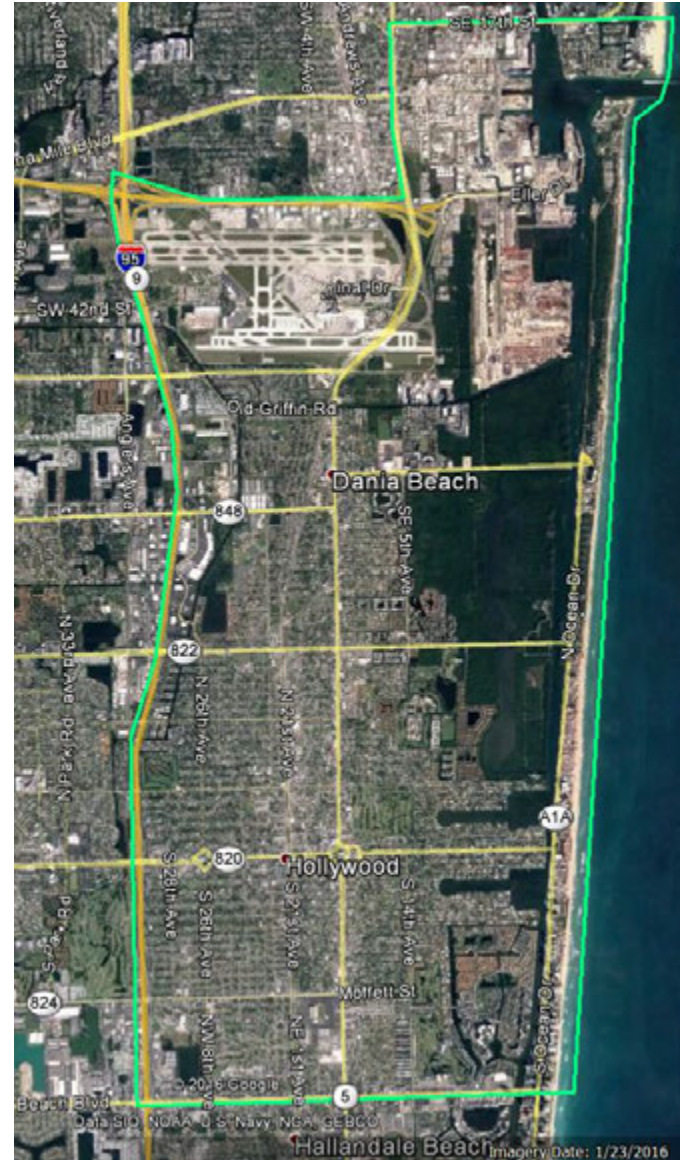
<http://www.microimages.com/documentation/html/tutorials.htm>

Pilot Project

- FDOT Central Office
- FDOT District 4
- Broward County
- Southeast Florida Climate Compact



Florida Department of Transportation



Closing.....Questions?



<http://www.fdot.gov/geospatial/>

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[Control](#)
[Right of Way Maps](#)

Welcome

Our office leads statewide surveying and mapping efforts through spatial technology expertise in support of Florida's transportation system. We support surveying and mapping activities statewide by providing policies, procedures, guidelines, and training. Our areas of expertise include: Aerial Surveying and Mapping, Location Surveying, Right of Way Mapping, and Geographic Mapping which includes distributing aerial photography, producing the Florida Official Transportation Map, and providing Geographic Information Systems (GIS) support for engineering and operations.

News

Surveying and Mapping (UAS)

An unmanned aircraft system (UAS) is an unmanned aircraft (UA) with associated support equipment, control station, data links, telemetry, communications, and navigation equipment necessary for operations. UA is considered an aircraft under both 49 U.S.C. § 40102 and 14 C.F.R. § 1.1. The potential uses of UAS range from infrastructure inspections, surveillance of crops, and aerial mapping to package delivery and event videography. With the lowering costs of UAS, the growth of many companies are looking to take advantage of this newly available technology.

Posted: May 25, 2016